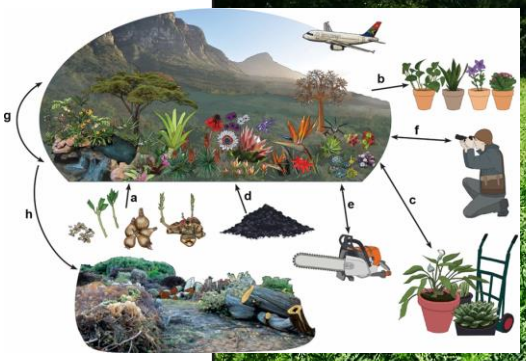
DSI-NRF Centre of Excellence for Invasion Biology

Annual Report

2021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EXECUTIVE SUMMARY

Reporting period	:	1 January 2021 - 31 December 2021
Name of Director	:	Prof. David M. Richardson
Name of CoE	:	DSI-NRF Centre of Excellence for Invasion Biology
Abbreviated CoE Name	:	Centre for Invasion Biology (C·I·B)
Host institution	:	Stellenbosch University

Preamble

2021 was another challenging year for the Centre for Invasion Biology (C·I·B). Funding cuts meant that we had to retrench some core staff and others resigned. This, along with Covid-19 regulations that prevailed for all of 2021, reduced the efficiency of many facets of the centre's activities. Despite such challenges, it was a productive year in terms of research outputs, although metrics in this regard (e.g. publications and student numbers) largely reflect inputs and work in previous years.

Efforts to secure funding for the C·I·B beyond March 2023 took up the lion's share of the Director's time and energy during 2021. Despite several very promising leads and protracted negotiations, only one substantial source of funding was finalized - this for a 3-year Research Chair in Invasive Species Management in Protected Areas funded by the Millennium Trust. The aim was to secure at least three such Chairs to serve as the pillars around which a "new C·I·B" would be structured.

Negotiations were held with Stellenbosch University regarding the university's newly launched School for Climate Studies with view to the C·I·B merging with the School in some way. Delays in appointing a Director and charting a clear course for the School were frustrating. What remains of the C·I·B (together with the newly funded Chair) will join forces with the School in 2023.

Despite the issues outlined above, the 2021 annual report is impressive. The C·I·B remains a world-class centre for the study of biological invasions.

Progress against Key Performance Areas

1 Research

The research outputs of the C·I·B in 2021 comprise 142 papers in peer-reviewed journals and four chapters in edited books. Several outputs appeared in high-impact journals, including *BioScience*, *Ecology Letters*, *Nature Communications* (2), *Proceedings of the National Academy of Sciences of the USA*, *Science Advances*, and *Scientific Reports* (3). Our research also featured prominently in the main journals specializing in biological invasions, namely *Biological Invasions* (9 papers) and *NeoBiota* (4 papers).

As always, our research contributions in 2021 ranged from basic to applied science. Many publications provide new insights that are directly relevant for policy and management. A few examples are (citations refer to publications listed in Appendix 1): a new method for quantifying range structure of invasive species to inform management (Cheney *et al*. 2021); a new approach for sowing seeds in active restoration of fynbos (Hall *et al*. 2021b); an assessment of the role of public awareness in ensuring effective management of invasive species (Jubase *et al*. 2021). International collaborations provide new insights on key facets of invasions science, for example: the crucial role of using accurate terminology in research and policy (Essl *et al*. 2021), the fundamental importance of seed banks in plant invasions (Giora *et al*. 2021), the utility of applying network science in addressing key concepts pertaining to invasions (Hui *et al*. 2021), and the separate (but crucially linked) trajectories in the evolution of invasion science and community ecology (Latombe *et al*. 2021).

2 Education and Training

The C·I·B supported 50 students (24 Masters; 25 PhD; 1 BSc Hons) and eight post-doctoral fellows during 2021. It is notable that a large proportion of our students and post-docs (100% for Hons; 44% for Masters; 48% for PhD and 29% for post-docs) did not rely fully (or at all) on NRF funding. This reflects the success of the C·I·B in leveraging funding to support students (but unfortunately not staff). Our students continue to address issues identified as important by our partners, and our alumni remain in demand for positions in academic institutions and conservation agencies within South Africa and, increasingly, abroad.

3 Networking

Covid regulations reduced opportunities for networking in 2021. Despite this, we held a very successful Annual Research Meeting (as a fully online event). Several small workshops were held.

4 Information Brokerage and Outreach

The C·I·B's Iimbovane Outreach Project had a very successful year in 2021. The project team conducted 41 school-based lessons at partner schools. Lessons included theory as well as fieldwork, enabling learners to develop basic practical scientific skills. Iimbovane reached a total of 959 high-school learners in 2021. No symposia were convened in 2021 due to Covid regulations.

5 Service Provision

The C·I·B made major contributions to the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) and continues to make inputs to projects associated with the National Status Report and ASRARP (Alien Species Risk Analysis Review Panel, a panel of experts co-ordinated by the South African National Biodiversity Institute [SANBI]). Four of the 25 ASRARP members are C·I·B core team members and three are C·I·B associates.

What was the gender impact of the C·I·B's work?

Women are well represented on the C·I·B's core team (25%), associates (41%), on the Stellenbosch hub staff (100%), the Iimbovane team (100%), post-docs (50%) and students (59%).

Red Flags (and opportunities)

Securing funding to ensure that the C·I·B's existence after 2023 was the top priority in 2021. Our efforts bore some fruit, notably with a generous donation from the Millennium Trust to fund a Chair in Invasive Species Management in Protected Areas. This will provide a crucial pillar around which to leverage further funding to support research and student training. Additional chairs will be crucial to ensure a critical mass of expertise to ensure that the C·I·B maintains its reputation for excellence nationally and internationally. The current financial situation worldwide poses severe challenges in this regard. However, the opportunity to reinvent and regrow the C·I·B with the emerging focus on global change at Stellenbosch University's School for Climate Studies (SCS) is the silver lining on this cloud.

A crucial ingredient in the success of the C·I·B as a CoE was the funding to support the "glue" that allowed the development and effective functioning of networks (notably the C·I·B's core team and research associates) that were fundamental in achieving most of its aims. Finding such "glue money" (e.g. to fund support staff) is a substantial challenge. Sharing key administrative personnel with the SCS will be important in this regard.

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1 RESEARCH

1.1 Objectives

Research at the C·I·B aims to reduce the rates and biodiversity impacts of biological invasions by understanding how these can be reduced and remediated through appropriate policy interventions. Our work also explores how interactions among global change drivers, especially climate change and biological invasions, potentially influence the impacts of biological invasions.

Our projects and integrated programmes of research address all aspects of the phenomenon of biological invasions, all taxonomic groups and all ecosystems, with a strong focus on South Africa. A better understanding of invasion patterns and processes is required, and options for management and remediation need to be explored in multiple ways. Each stage in the invasion process (pre-introduction; initial incursion; expansion; and dominance) demands special tools, insights and types of study. The C·I·B is at the forefront of such developments nationally and has been a major player in the field of invasion science internationally.

Besides the aspects attached specifically to the aforementioned aspects, the C·I·B undertakes work under several overarching themes: Biological foundations, model systems, human dimensions, basic inventories, modelling capacities, policy formulation and risk assessment. This suite of themes provides the scope for cutting-edge work in invasion science, while providing opportunities to draw in students from diverse biological fields (from fundamental to applied) and many other disciplines.

The research outputs of the C·I·B in 2021 comprise 142 papers in peer-reviewed journals and 4 chapters in edited journals. Several outputs appeared in high-impact journals, including *BioScience*, *Ecology Letters*, *Nature Communications* (2), *Proceedings of the National Academy of Sciences of the USA*, *Science Advances*, and *Scientific Reports* (3). Our research also featured prominently in the main journals specializing in biological invasions, namely *Biological Invasions* (9 papers) and *NeoBiota* (4 papers). As always, our research contributions in 2021 ranged from basic to applied science. Many publications provide new insights that are directly relevant for policy and management. A few examples are (citations refer to publications listed at the end of the annual report): a new method for quantifying range structure of invasive species to inform management (Cheney *et al*. 2021); a new approach for sowing seeds in active restoration of fynbos (Hall *et al*. 2021); an assessment of the role of public awareness in ensuring effective management of invasive species (Jubase *et al*. 2021). International collaborations provide new insights on key facets of invasions science, for example: the crucial role of using accurate terminology in research and policy (Essl *et al*. 2021), the fundamental importance if seed banks in plant invasions (Giora *et al*. 2021), the utility of applying network science in addressing key concepts pertaining to invasions (Hui *et al*. 2021), and the separate (but crucially linked) trajectories in the evolution of invasion science and community ecology (Latombe *et al*. 2021).

1.2 Progress

Short-term strategic research priorities are grouped under the following major headings: biodiversity foundations; acacias as model systems for understanding invasions and impacts; detection, demonstration, responses and remediation; global environmental change and ecosystem services; and human dimensions. Further details of many research projects are available on the C·I·B's web site (http://academic.sun.ac.za/cib/). The projects summarized below provide but a flavour of the wide range of disciplines, taxa, spatial and temporal scales, and scientific approaches in the C·I·B's research during 2021.

Research in 2021 focussed on many of the most pressing issues in invasion ecology and the full spectrum of focus areas identified in the C·I·B's strategic plan. Our research addresses fundamental issues related to the biology of invasive species, aspects of invaded ecosystems, invasion processes, and many facets of the human dimensions of invasions.

1.2.1 Biodiversity foundations – baseline data for pre-invasion states and comparisons

Recognizing the significance of the foundational aspects of biology and the social sciences within the context of invasion biology, and the fact that human activities can often not be clearly separated from natural processes, the C·I·B has undertaken much foundational work over its lifespan. Such work has also been crucial for drawing in students and collaborators who are particularly interested in 'the workings of nature' rather than on particular framings of biological invasions. The example reported on in this report focusses on pollination networks (Rodger *et al*. 2021). Although the landmark paper described here does not explore the role of invasions explicitly, invasions are a widespread disruptor of plant reproductive mutualisms and improved understanding of the architecture of plant-pollinator networks is a crucial requirement for work to explore the role of invasions.

First global estimate of importance of pollinators for seed production in plants

About 175 000 plant species (about half of all flowering plants) rely mostly or completely on animal pollinators to make seeds and to reproduce. Declines in pollinators could therefore cause major disruptions in natural ecosystems. This is the finding of a landmark paper entitled "Widespread vulnerability of plant seed production to pollinator declines," led by James Rodger, a post-doctoral fellow in the Department of Mathematical Sciences at Stellenbosch University (SU) (and a former C·I·B PhD student). This study (Rodger *et al*. 2021. *Science Advances* **7** DOI: 10.1126/sciadv.abd3524) provides the first global estimate of the importance of pollinators for plants in natural. The research involved 21 scientists affiliated with 23 institutions from five continents, including C·I·B core team member Cang Hui.

Co-author Tiffany Knight from the Helmholtz Centre for Environmental Research in Germany says that recent global assessments of pollination have highlighted a knowledge gap in our understanding of how dependent plants are on animal pollinators. “Our synthetic research addresses this gap, and enables us to link trends in pollinator biodiversity and abundance to consequences for plants at a global level,” she explains.

While most plants are animal-pollinated, most also have a level of auto-fertility. This means they can make at least some seeds without pollinators, for example by self-fertilisation. However, until this study, the question, “How important are pollinators for wild plants?” did not have a clear answer at the global level.

The researchers used the contribution of pollinators to seed production — measured by comparing seed production in the absence of pollinators to seed production with pollinators present — as an indicator of their importance to plants. Data on this existed but were spread out in hundreds of papers each focusing on pollination experiments on different plant species. To address this problem, the researchers consolidate the information in a set of databases: James Rodger developed the Stellenbosch Breeding System Database; Tiffany Knight, Tia-Lynn Ashman and Janette Steets led the sPLAT working group that produced the GloPL database; and Mark van Kleunen (another former C·I·B post-doc) and Mialy Razanajatovo produced the Konstanz Breeding System Database. These databases were then combined to form a new database for the current study including data from 1 528 separate experiments, representing 1 392 plant populations and 1 174 species from 143 plant families and all continents except Antarctica.

The findings show that without pollinators a third of flowering plant species would produce no seeds and half would suffer an 80% or more reduction in fertility. Although auto-fertility is common, it by no means fully compensates for reductions in pollination service in most plant species.

> “Recent studies show that many pollinator species have gone down in numbers, with some even having gone extinct. Our finding that large numbers of wild plant species rely on pollinators shows that declines in pollinators could cause major disruptions in natural ecosystems,” warns Rodger.

Co-author Mark van Kleunen says it is not a case of all pollinators disappearing: “If there are fewer pollinators to go around, or even just a change in which pollinator species are most numerous, we can expect knock-on effects on plants, with affected plant species potentially declining, further harming animal species and human populations depending on those plants. Pollinators are not only important for crop production, but also for biodiversity. “It also means that plants that do not rely on pollinators, like many problematic weeds, might spread even more when pollinators continue to decline,” he adds.

Co-author Joanne Bennet who curated the GloPL database says another disconcerting factor is the positive feedback loop that develops if pollinator-depending plants decline or go extinct.
“If auto-fertile plants come to dominate the landscape, then even more pollinators will be negatively affected, because auto-fertile plants tend to produce less nectar and pollen.”

“All is not doom and gloom however” says Rodger. “Many plants are long-lived; this opens a window of opportunity to restore pollinators before plant extinctions occur due to the lack of pollinators” (see Fig. 1).

“We lack high quality long-term monitoring data on pollinators in Africa for example, including South Africa, although some work has been started in this regard. We hope that our findings will stimulate more of this kind of research, so that we can detect pollinator declines and mitigate their impacts on biodiversity,” concludes Rodger.

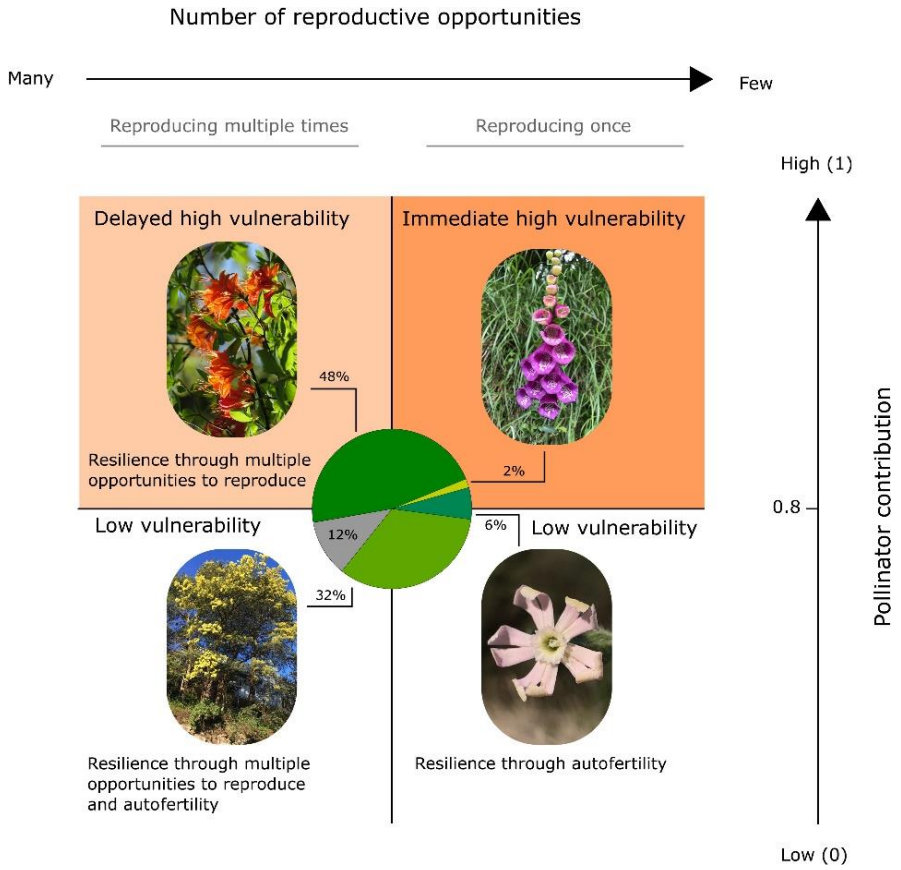


Fig. 1. Vulnerability of flowering plants to future pollinator declines through pollinator contribution and opportunities for reproduction. Pollinator declines will have little impact on seed production of species with low a pollinator contribution (PC) metric (bottom two quadrants). Plant species with high PC (top two quadrants) will experience reduced seed production if their pollinators decline. However, those that are longer lived and have multiple opportunities to reproduce (top left quadrant) are only expected to experience population declines after a lag period, whereas short-lived species that reproduce only once in their lives (top right quadrant) may experience more rapid population declines when their pollinators decline. The 12% of angiosperm species that are resilient to pollinator decline due to wind pollination are shown by the grey slice (From: Rodger *et al*. 2021; *Science Advances* **7** DOI: 10.1126/sciadv.abd3524).

1.2.2 Model groups and systems for understanding invasions and their impacts

Several key groups of organisms and settings/contexts (including Australian acacias, the harlequin ladybird, *Xenopus laevis* and environments such as urban areas and agricultural contexts) were, for various reasons, selected as model groups or systems for gaining important insights on the full range of challenges and management options associated with introduced species in South Africa. Not all of these model systems receive research attention every year. During 2021, substantial work was undertaken on many aspects of acacias and *Xenopus laevis*. Some aspects of this work are summarized below.

1.2.2.1. Model taxonomic groups

Acacias as a model system for understanding invasions and impacts

Invasive Australian *Acacia* species (wattles) have commercial and other benefits in certain contexts, but major negative impacts in others. They also have substantial influence (positive and negative, depending on geographical and socio-political context) on ecosystem services. Introductions and plantings of wattles in South Africa and elsewhere have created a valuable natural experiment for elucidating many key aspects of invasions science. Wattles have featured prominently in research undertaken at the C·I·B since its inception, and they featured prominently in the C·I·B's research output again in 2021. Research on this taxon addresses, among other things the genetics of invading populations and their impacts on soils in invaded habitats.

Australian acacias are genetically highly diverse across the globe

Australian acacias are among the world's worst (most widespread and most damaging) invasive plants. Their success has been heavily shaped through their usage by humans for various purposes. C·I·B Research Associate Jaco Le Roux, Director Dave Richardson and core team member John Wilson, with colleagues from the University of Lisbon in Portugal, undertook a meta-analysis of the genetic diversity of 37 Australian *Acacia* species.

The paper, led by PhD student Sara Vicente at Macquarie University, Australia, focused on molecular genetic diversity of both native and invasive populations of acacias. Information on the invasion history such as year of first introduction, number of introductions, and reasons for introduction, were recorded for all species.

The study found that *Acacia* species have been introduced around the world for various purposes, related to land reclamation, horticulture, fuelwood, tannin production, and ornamental plantings. The earliest introductions were to South Africa, as far back as the 1820s, while some species were introduced as recently as the 1970s - into Asia.

The study found that most invasive acacia populations resulted from multiple introductions as a result of high propagule pressure. Because of this, most invasive acacia populations have high genetic diversity and did not experience inbreeding. The introduction of high genetic diversity likely also provided opportunities for pre-adapted phenotypes to be introduced, while genetic admixture between different source populations could have led to novel invasive genotypes. The high levels of genetic diversity in invasive populations also suggest that Australian acacias have the capacity to adapt to their new environments.

Vicente says, “While we know the extraordinary invasion success of acacias is closely linked with extensive human usage and dissemination, our study also suggests that high adaptive capacity, as afforded by high levels of genetic diversity, is a fundamental reason for their success.”

Invasive Australian acacias change fynbos soil functioning

Microbial communities of fynbos soils have not received as much attention as aboveground components. This is especially true regarding the impacts of invasive plants on these communities. However, this was explored by Jan-Hendrik Keet (C·I·B student) and Allan Ellis (Department of Botany & Zoology, Stellenbosch University), Cang Hui (C·I·B core team member), Ana Novoa (Czech Academy of Sciences, Czech Republic), and Jaco Le Roux (C·I·B Associate).

Proper ecosystem functioning depends on the activities of soil microbes, such as bacteria and fungi, and is affected by the local plant communities. Soil microbes play crucial roles, for example by regulating nutrients in the soil by secreting extracellular enzymes. This, in turn, affects the plant communities that grow in these soils, thus creating plant-microbe feedback loops. Dense stands of invasive plants (like Australian acacias) are not only expected to change the chemistry of the soil, but also potentially the make-up and functions of soil microbial communities.

To investigate the impacts of invasive acacias on fynbos soil bacterial communities and their functioning, the research team sampled five sites in the Cape Floristic Region (one near Somerset West, three near Stanford, one near Vermaaklikheid on the Agulhas Plain) that capture a large degree of variation in fynbos soils.

The study showed that acacias change the soil chemistry by increasing the levels of nitrogen-containing compounds, carbon and pH of the soil. Acacias also change the make-up of bacterial communities in the soil, but not the diversity. Finally, the research team discovered that acacias elevate soil phosphatase and urease activity, enzymes that regulate the release of phosphorous and nitrogen, respectively, from organic matter in the soil (Keet et al. 2021*; Microbial Ecology* **82**, 704–721).

Interestingly, changes in both the chemical properties of the soil and its bacterial community composition under acacia invasion correlated with phosphatase activity. This means that not only do

acacias alter soil chemistry and bacterial communities, they also alter soil functionality. But, as is often the case ecosystem interactions, these impacts appear to be specific to local site conditions, and as such the plant-soil feedbacks underlying these impacts remain unclear.

“This study provides valuable information on how an essential, but often neglected, component of ecosystems is affected by invasive plants, namely soil microbial communities,” says lead author Keet.

He added that “invasive plants change soil chemistry and the composition of soil microbial communities, and that in turn correlates with elevated soil enzyme activities. The question is now: how long do these changes persist after the invasive plants are removed, and how do such changes impact the re-establishment of native plants, for example during restoration attempts?”

Xenopus laevis **- A globally significant invasive amphibian**

The highs and lows of being a tadpole

Some species are wide ranging, either across latitudes or from montane areas to the sea. The African clawed frog, *Xenopus laevis*, is one such species that occurs from the sub-tropical regions at sea-level to ~3000 m in the Lesotho highlands. C·I·B Honours student Carla Wagener collected adults from (close to) sea-level in iSimangaliso National Park, and up at ~2000 m at the foot of the Drakensburg mountains (Wagener et al. 2021; *Journal of Experimental Biology* **224** jeb233031).

Adults were brought back to the lab in Stellenbosch and bred in a common garden experiment. Crucially, males from high altitude were also cross-bred with females from low altitudes, and vice versa. With the progeny that resulted from these crosses, Wagener measured their swimming performance at different temperatures. We knew that tadpoles swim faster as higher temperatures, but wanted to determine the difference in temperature of peak performance between the two populations adapted to different altitudes - and what would happen when adults were crossed.

The results were amazing. The difference in peak performance between the two populations was ~15 C (Fig. 2), but when parents from different populations were crossed, they followed the performance peak of the mother. It could be that individuals from high altitude are carrying a gene for performing well at low temperatures in their mtDNA, which is maternally inherited. Although there are other explanations, the common garden nature of this experiment suggests that these populations have strong adaptations to their altitudes that are can be inherited when mixed, instead of becoming diluted.

The findings of this work have some relevance for invasive populations, particularly in France where populations are made up of many different genetic sources. It has been speculated that the reason that they have done so well in the much colder French midlands is because of this variation in genetics. This study by Wagener *et al*. suggests that progeny of different populations retain their

peak performance at different temperatures, and that could explain some of the benefits seen by invasive populations in France.

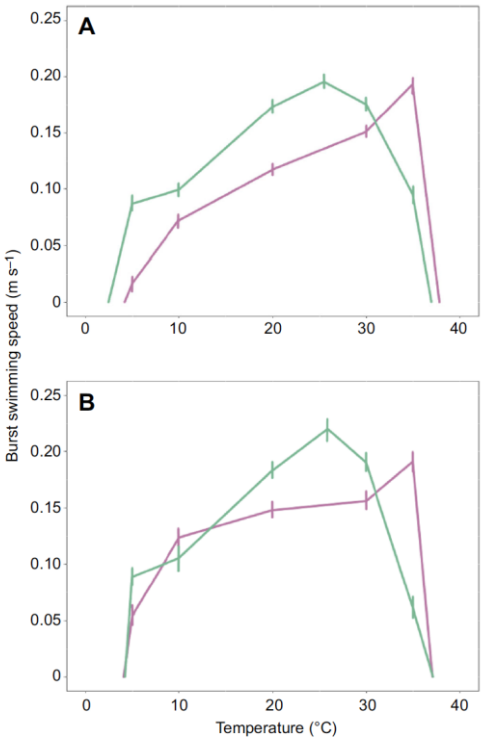


Fig. 2. Maximum burst swimming speed with standard errors at five test temperatures in *X. laev*is tadpoles. (A) High-altitude parental origins (green line, N=30 for each test temperature) and low-altitude parental origins (pink line, N=30 for each test temperature). (B) Crossed parental origins with high-altitude maternal origins (green line, N=20 for each test temperature) and crossed parental origins with low-altitude maternal origins (pink line, N=20 for each test temperature). The interaction between parental origin and temperature significantly affected maximum burst swimming speed of tadpoles (GLMM, P<0.05). (From: Wagener *et al.* 2021; *Journal of Experimental Biology* **224** jeb23303)

1.2.2.2. Model systems

Invasions in urban areas

The C·I·B's participation in the Global Urban Biological Invasions Consortium (GUBIC; https://cubes-labs.com/gubic/) provides a useful focus and benchmarking opportunities for our work on invasions in urban areas. One example of such work is summarized below.

Urban toads show themselves to be bolder – before and after invasion

Many of us are familiar with urban commensal species – those that have adapted to life in towns and cities. Some of these urbanised species are then introduced to novel systems, and go on to become invasive. This raises the question of whether their ability to shift their behaviour in urban populations gives these city-dwellers an advantage within an invasive range.
C·I·B Post-doc James Baxter-Gilbert collected toads from urban and rural areas in their native (Durban, South Africa) and invasive (Reunion & Mauritius) ranges. He and his co-workers then examined differences in boldness and exploration in toads from each site. Because the invasion route of these toads was known from previous research at the C·I·B, Baxter-Gilbert was able to reconstruct whether trends in these behavioural traits changed along the invasion route.

Have invasive toads become bolder than their native counterparts? What Baxter-Gilbert found was that populations in the native range became bolder in urban populations, and that these increased boldness levels were maintained once toads were moved from urbanised populations in the native range and introduced to urban areas in novel regions.

Overall, urban toads were consistently bolder than those in rural situations. Interestingly, along the invasion route there has also been a reversal from bolder toads to shyer toads once they left the urban areas in the invaded ranges and colonised more natural and rural settings – returning to the normal baseline levels of their rural native populations.

This tells us that benefits gained by these bold traits are sufficient to repeatedly manifest themselves when toads invade urban settings, but that rural toads gain consistent benefits from being less bold. Moreover, this study was able to show that these toads are able to switch between these different behavioural phenotypes no matter where they are introduced.

“This finding shows us more of the flexibility of these toads as invaders,” said Baxter-Gilbert. “If they are moved from native or invasive ranges, they seem to be able to adaptively shift their behaviour to suit both urban and rural living.”

1.3 Detection, elucidation and quantification of impacts and risk analysis

Addressing uncertainty in impact assessments for alien species

Impact classification schemes for alien taxa are becoming more prominent as the threats posed by biological invasions increase. A recent study found that despite a high variety of types of uncertainties in impact assessments (some of which cannot be eliminated easily), communicating their existence, cause and variety can lead to more useful and reliable outcomes of impact assessments.

In 2018 at a workshop in Melbourne, Australia, organised by former C·I·B core team member Melodie McGeoch (now at La Trobe University in Australia) in collaboration with Australia's Invasive Species Council, scientists from all over the world including C·I·B core team member Sabrina Kumschick, tackled the issue of uncertainty in impact assessments. Due to the importance of impact assessments in the management of alien species, it is crucial to understand the uncertainties associated with such assessments, their causes, and effects on classifications.

The scientists assessed 100 alien insect species according to the magnitude of their impacts using the Environmental Impact Classification for Alien Taxa (EICAT) which has been adopted as a global standard for classifying alien species by the International Union for the Conservation of Nature (IUCN). Each species was classified independently by two assessors and outcomes compared to explore the reasons for differences in classifications. These differences can show us where and why uncertainties arise.

Discrepancies in assessments between assessors were relatively common, with initially more than half of the assessments differing between the two assessors. These differences were reduced after assessors discussed their rationales for the assessments. Therefore, it would be ideal if impact assessments were performed by several people, independently or in groups, and discussed to reach consensus. However, while this study shows how some of the uncertainty can be reduced, it also shows that uncertainty can be perpetuated along the assessment process.

Uncertainty often starts in the description of results in the literature used as evidence for impacts. EICAT classifies impacts into mechanisms (how do the alien species affect native species) and magnitude (to what extent is the native species affected) (Fig. 3). "If these variables are not clearly described in the literature, it is difficult for an assessor to assign an appropriate EICAT category and mechanism," says David Clarke, PhD candidate at Monash University who was lead author of the paper (Clarke *et al*. 2021; *Ecosphere* **12**, DOI: 10.1002/ecs2.3461).

In some cases, assessors extrapolated information provided in the literature based on their own expert knowledge, which was a common source of discrepancies specifically if one of the assessors was particularly familiar with a certain species. While this is not following EICAT guidelines and should generally be avoided in evidence-based impact assessments, authors of the study suggest that it might be useful to include expert opinion to inform management decisions, specifically in cases where evidence is limited. However, for official IUCN EICAT assessments, only available evidence should be included, and assessed as objectively as possible.

Furthermore, many differences between assessors were due to different pieces of evidence included in the assessments. EICAT assessments need to include all available literature on impacts of a given alien species. "It is very important that a thorough literature search is conducted to ensure all available records of impact are included in the EICAT assessment," says Sabrina Kumschick. "For well-studied species, it can help to divide the work between several people, or to do assessments in

groups and discuss outcomes. Another benefit of such an approach is that if first assessments are done properly, it takes little effort to add new pieces of evidence and keep assessments up to date."

It is also important to note that some types of uncertainty cannot be eliminated in impact assessments due to constraints such as natural variation in the systems studied. However, it is important to acknowledge which sources of uncertainty are present, and which of those can be addressed in order to get more useful and transparent impact assessments. Research leader Melodie McGeoch says, "Studies such as this are essential to support and provide evidence for and confidence in policy tools such as EICAT, amongst both scientists and decision makers."

"This study is an important contribution to making the EICAT impact assessment process more transparent and consistent," says co-author Sabrina Kumschick who is also Chair of the IUCN's EICAT Authority which oversees the development of EICAT guidelines, assessments and reviews for the IUCN. "Many of the recommendations made in this study have therefore already been incorporated into the official IUCN EICAT Standard and guidelines, and the broader insights and recommendations in this publication will be useful for assessors applying EICAT."

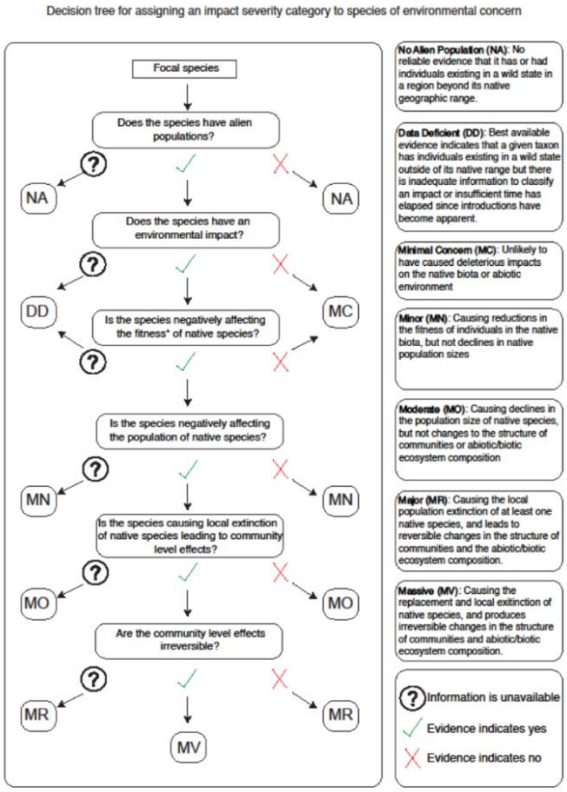


Fig. 3 Schematic representation of decisions required to assign an impact category in EICAT using available evidence. (Clarke *et al*. 2021; *Ecosphere* **12**, DOI: 10.1002/ecs2.3461).

Barcoding as a tool to track emerging pests: the case of the sugarcane long-horned beetle

Identifying agricultural crop pests quickly and reliably is critical for tracking their spread and to apply suitable control measures where needed. However, the identification of insect pests is often hampered by the lack of taxonomic expertise, especially in complex and poorly known tropical groups. DNA barcoding is often used as a supporting tool to identify species in the context of invertebrate pest management but relies on comprehensive and well-curated molecular databases. C·I·B post-doc Marion Javal and C·I·B core team Member John Terblanche led a recent study that involved entomologists from other institutions and industry partners to better manage an emerging sugarcane pest in South Africa.

The sugarcane long-horned beetle (*Cacosceles newmannii*) is native to Mozambique, eSwatini and South Africa. Larvae of this beetle were found in abundance in 2015 feeding on commercially grown sugarcane in KwaZulu-Natal, South Africa. This beetle digs galleries into the sugarcane stool and feeds inside the stalks causing significant crop damage, thus impacting cane farm yields (Fig. 4). The reasons and the mechanisms underlying the rapid emergence of the beetle onto sugarcane from feeding on its indigenous host plants remain unclear, but it was clear to the team that the species has the potential to spread rapidly and cause considerable agricultural and economic losses. When tracking the potential spread of this pest, it was observed that many other related Prioninae (a subfamily of long-horned beetles) were trapped around the sugarcane fields, resulting in potential confusion for the pest scouting or monitoring teams who are keen to prevent further outbreaks. Furthermore, museum records cast little light on this group of beetles partly owing to taxonomic revision of the group and morphologically similar developing life-stages (e.g. larvae).

Fig. 4. Sugarcane long-horned beetle (*Cacosceles newmannii*) larva in a sugarcane stalk. Photo: Marion Javal.

By assembling beetle samples from South Africa, Madagascar, Gabon and Democratic Republic of the Congo and obtaining DNA sequences from diverse and closely-related species, the team was able to

compile a comprehensive barcoding database to address this pest problem in the region. This study therefore not only generated DNA barcodes of the emerging pest sugarcane long-horned beetle but also of other Afrotropical Prioninae to facilitate their rapid identification by plant protection officers. The team compiled a curated DNA barcoding reference library for 70 specimens of 20 named species of Afrotropical Prioninae with a focus on the genus *Cacosceles*. The barcode database will allow the molecular identification of the most common species of southern African Prioninae, and can be updated and expanded as additional barcoding data become available.

“This paper and the barcoding database we produced is a valuable tool for rapid and accurate species identification in the region for a poorly studied group of insects,” says Marion Javal. She adds, “It is extremely useful in the context of pest management but also is readily available in the public domain to be accessible to multiple stakeholders and facilitate advances in the pest management program.”

Trout impact on distributional patterns of native fish species

A fish survey by C·I·B PhD student Lerato Maimela (University of Pretoria) and C·I·B core team members Chris Chimimba (University of Pretoria) and Tsungai Zengeya (SANBI) in the headwaters of the Blyde River, Mpumalanga, revealed that Rainbow trout (*Oncorhynchus mykiss*) invasions have reduced the abundance and divided the community structure of native fish species.

For over a century, alien predatory fish such as Rainbow trout have been introduced into lakes and rivers in South Africa for sport fishing and aquaculture. However, most of the habitats that are suitable for trout, such as mountain headwater streams, are also inhabited by endemic and range restricted river minnows. The upper catchments of the Blyde River headwaters are home to the endemic and range restricted river minnow, the Treur River barb (*Enteromius treurensis*). Populations of these native species historically used to occur throughout the catchment but have since been significantly reduced and fragmented by the introduction of alien predatory fish.

The fish survey revealed that there was low abundance of native species, specifically, the Treur River barb that had 96% of its population reduced in areas were Rainbow trout occurred (Fig. 5). In contrast, native species populations were abundant in several sections of the upper catchment that are free of trout invasions. These river sections have managed to remain invasion free largely because of natural biogeographic barriers such as waterfalls that have prevented upstream migration by introduced Rainbow trout, and there are also located in protected areas were human facilitated fish introductions are prohibited.

Fig. 5. Lerato Maimela at the uninvaded sites by the first waterfall in the Christmas pools of the Blyde River where a remnant population of the Treur River barb (*Enteromius treurensis*) occurs. (Photo: Lee-Anne Botha)

This finding is consistent with other studies that have shown that introduced alien predatory fish can have a significant effect on fish communities and highlighted the need to prevent human-facilitated introductions in biodiversity sensitive areas such as mountain headwater streams that are inhabited by endemic and range restricted minnows.

"We believe that the further spread of trout into biodiversity sensitive areas such as mountain headwater streams that are currently invasion free and inhabited by endemic and range restricted species should be discouraged," says Maimela, "as some of the species are critically endangered and will likely go extinct if no conservation measures are implemented."

1.4 Global environmental change and ecosystem services

Retooling invasion science to deal with rapid global change

Invasion science must adapt to meet growing societal demands and biosecurity challenges in the face of rapid global environmental change. This task was addressed at a workshop during the NEOBIOTA conference in Dún Laoghaire, Ireland, in September 2018 that was attended by several researchers affiliated with the C·I·B.

A publication led by C·I·B Associate Anthony Ricciardi of McGill University in Canada and with several other C·I·B-affiliated researchers as co-authors summarized the findings of this workshop and subsequent deliberations (Ricciardi *et al*. 2021. *Environmental Reviews* **29**, 119 – 141). The paper identified four critical priority areas that need to be addressed by the field (Fig. 6).

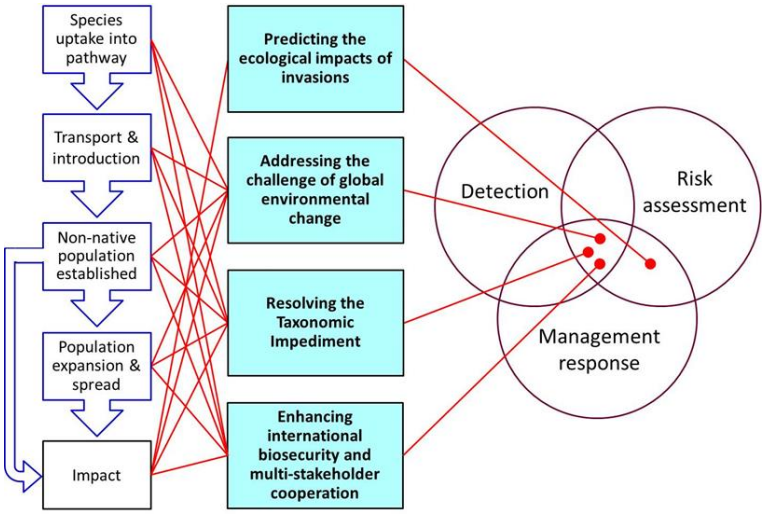


Fig. 6. Four priority issues (centre column) for invasion science. Each issue is implicated in one or more stages of the invasion process (left column), and in the impact of the invader (which can occur at any stage from introduction to establishment to spread) and in the detection, risk assessment, and management of invasion threats (Ricciardi *et al*. 2021; *Environmental Reviews* **29**, 119 – 141).

One priority is the need for novel methods to forecast the ecological impacts of invasions. Risk assessments of invasions are confounded by environmental context dependencies and lag times between introduction and impact. A related priority area is to understand how invasive species interact with multiple stressors, particularly climate change. The researchers suggest that the innovations in theory and methods required to address these issues could be found by exploring linkages with other disciplines. For example, factors promoting the emergence and spread of novel infectious diseases might be better understood through collaborations between biomedical researchers and invasion biologists.

Another critical issue is the steady global decline in taxonomic expertise. If not reversed, this will lead to increasing misidentifications and impaired detection of invasion threats. The erosion of our capacity to recognize biodiversity and distinguish non-native from native species poses severe consequences for biosecurity that cannot be adequately mitigated by new molecular technologies alone. The problem is especially worrying in marine ecosystems and for microorganisms in general.

“Scientific understanding of the processes that control the diversity, abundance, and distribution of non-native species depends upon the quality of taxonomic data. We now face a critical and mounting predicament on this front: The steady global erosion in training and expertise in systematics means that we simply lack the taxonomic support to accurately identify many, if not most, taxonomic groups in freshwater, terrestrial, and marine habitats,” – explains one of the co-authors, James T. Carlton.

Taxonomic expertise should be cultivated through infrastructure support (such as cybertools and properly curated specimen collections) and by re-establishing training programmes focussing on both classic and advanced taxonomic skills. Governments and academia must employ qualified

taxonomists to handle the burden of increasing rates of invasion by a wide range of organisms transported across the planet through human activities.

Finally, the authors call for enhanced international cooperative biosecurity. Contemporary national biosecurity programs are generally designed to protect the interests of individual countries and scant attention is given to the "greater good"—that is, protecting all nations from invasions. A key consideration is the tendency of spreading organisms to invade new regions from locations in which they have already established ("bridgeheads")(Fig. 7). The implication of this phenomenon is that successfully preventing a species from invading a bridgehead region will bring benefit to multiple countries elsewhere in the world by reducing its opportunities to spread within a global dispersal network.

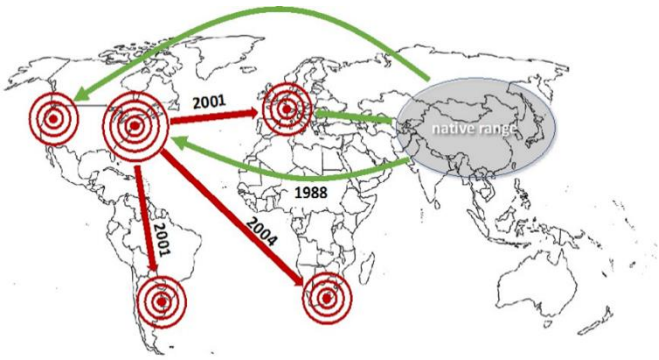


Fig. 7. The "bridgehead effect" of the global spread of the harlequin ladybird beetle *Harmonia axyridis*, based on genetic analyses by Lombaert *et al*. (2010; *PLoS ONE* **5**, e9743). The beetle was introduced intentionally as an insect biocontrol agent in some regions (shown in green). From these bridgehead regions, the beetle was transported inadvertently to other continents. Most of the global spread of this species has originated from non-native populations in Eastern North America (From: Ricciardi *et al*. 2021; *Environmental Reviews* **29**, 119 – 141).

"We must recognize invasions as a challenge to global biosecurity", says Ricciardi. "The world's recent experience with the SARS-CoV-2 virus provides an excellent, albeit extreme, example of the bridgehead phenomenon. Cooperation among countries to eradicate or control invasive species in key bridgehead regions should yield broad international benefits."

Overall, invasion science must continue to evolve. This paper offers guidance on how the field should adapt to an era of burgeoning human influence, novel stressors, and rapid environmental change.

"Lessons learned from deliberations during the preparation of this review have been extremely useful and have already being applied to reshape the research agenda for invasion science" says C·I·B Director Dave Richardson, a co-author of the paper.

1.5 The human dimensions of biological invasions

Horticultural trade drives establishment success in alien ferns

Much work at the C·I·B focusses on the role of human activities as drivers of invasions. Improved understanding of such factors is crucial for developing long-term strategies to reduce the extent and impacts of invasions.

The high demand for ornamental plants globally, combined with modern and increasingly efficient modes of trade (i.e., e-commerce), highlights that the horticultural industry is a subject of major conservation concern. Historically, ferns are well documented as being a popular ornamental plant group and recent studies have highlighted their high propensity towards invasion. Despite this, no studies have considered the role of trade as a driver of invasiveness in this large plant group.

This topic was tackled in a recent study led by C·I·B-funded PhD student Emily McCulloch-Jones from Nelson Mandela University (NMU). Additional researchers affiliated with NMU, Tineke Kraaij and Herve Fritz, as well as South African fern expert Neil Crouch were co-authors (McCulloch-Jones *et al*. 2021; *Biological Invasions* **23**, 3583–3596).

The study considered six major trading countries across the globe and showed that successful establishment in traded alien ferns is influenced by both species and market traits, specifically trade through e-commerce and the number of varieties and cultivars available for a species (a proxy for the effects of horticultural manipulation and ecotypic variation) (Fig. 8).

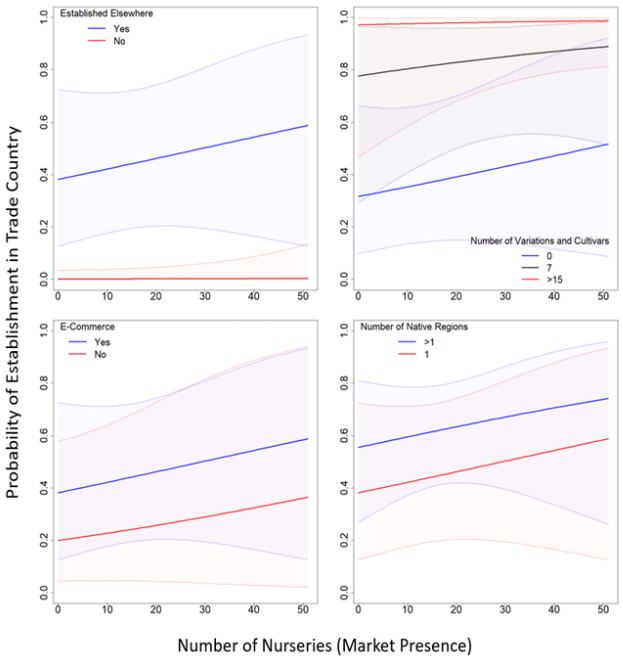


Fig. 8. The relative probability of a traded alien fern species becoming established in its country of trade in relation to market presence (i.e., the number of nurseries selling a species) and other significant predictor variables. (From: McCulloch-Jones *et al*. 2021; *Biological Invasions* **23**, 3583–3596).

By consulting horticultural catalogues to identify introduced species, i.e., adopting a horizon-scanning approach, the study identified 382 traded ferns, 261 of which were traded as aliens. The study further identified 29 species of traded alien fern that have successfully established elsewhere but currently have the status of introduced in their country of trade.

The researchers suggest that these species should be closely monitored and recognised as potential invaders present in trade. Some invasive species negatively affect their invaded environment, for example, large colonies of Holly fern (*Cyrtomium falcatum*), which is native to Asia, compete for habitat along the rocky coasts of Western Europe and South Africa. Holly fern also readily colonises man-made structures in coastal towns (Fig. 9).

Fig. 9. The invasive Holly fern *(Cyrtomium falcatum*) colonising a wall in the town of Hermanus, South Africa (Photo: E. McCulloch-Jones).

The authors also highlight the importance of apogamy, which permits the production of young plants without fertilization and allows for more rapid maturation of sporophytes and thus the earlier production of spores. Apogamous species such as Holly fern and Tassel fern *(Polystichum polyblepharum*) were identified as highly traded in the study. The researchers suggest that consideration of apogamy in other traded alien ferns will be useful in future studies that assess invasive potential.

“There are still so many questions surrounding alien ferns, but it is evident, at least, that their spread is most dominantly promoted through horticultural trade. It is great to have an inventory of species and some indication of their propagule pressure in different parts of the world. This is useful information as it has a tangible output and provides direction towards the management of current and future fern invasions” – Emily McCulloch-Jones.

It is likely that there are significantly more alien ferns across the globe than currently documented, given that the desktop approach applied in this study identified an additional 104 introduced species of alien fern across six countries when compared with a recent study (Jones et al. 2019) which identified relatively few introduced species at a global scale.

"It is so important to identify species introductions from their source. It is most likely that we identified more introduced species in this analysis compared to the previous study due to our survey approach, which considered nursery catalogues rather than formal inventories on alien and native flora. Furthermore, it is likely that there are still more alien fern species in the market than what we could detect." – Emily McCulloch-Jones.

The authors suggest that their methodology of screening horticultural catalogues for traded alien fern species allows for the early detection of introduced species and is an approach, which should be implemented globally as a means to inform policy and legislation surrounding potential invaders introduced through trade. The full trade data set is still being assessed, following which the authors hope to provide country-specific management recommendations.

Non-native small mammal species for sale in South Africa

Small mammals are among the most charismatic animals sold as pets around the world. Increasing trade for these pets has resulted in several species releases and escapees from captivity. Consequently, several small mammal pets have become invasive, with significant impacts on crops of agricultural importance, biodiversity, human social wellbeing, and the economy. In addition, some threatened species have become invasive in their introduced ranges, for example, the European rabbit (*Oryctolagus cuniculus*).

In South Africa, this pet trade is growing, and most of the species are sold online and in physical pet stores. Ndivhuwo Shivambu (C·I·B PhD student), Tinyiko C. Shivambu (C·I·B. PhD student), and Colleen Downs (C·I·B core team member) surveyed online trade and physical pet shops across South Africa to determine the degree of trade in non-native small mammals (Shivambu *et al*. 2021; *Management of Biological Invasions* **12**, 294–312).

In total, 122 pet shops selling 19,391 individuals representing 16 species were documented, while for online sales, seven websites selling 2,681 individuals representing 24 species were recorded. Of the 24 recorded species for sale, seven have become invasive through pet trade escapees and releases in other countries. The most dominant species in both online and pet stores were the Norwegian rat (*Rattus norvegicus*), guinea pig (*Cavia porcellus*), European rabbit and the house mouse (*Mus musculus*). About 46% of the species are listed under the Convention on International Trade in Endangered Species (CITES) and this includes most of the primate species. The recorded species' price ranged from ZAR9.00 to ZAR12,000.00, with primate species sold at relatively higher prices than other groups. Species found to be most popular, cheaper, not listed on CITES, least concern and invasive elsewhere pose a particular invasion risk to South Africa. Given this, the study recommends that sale of these species should be regulated to prevent future invasions and possible impacts.

"We believe that potential impacts of non-native small mammals can be mitigated through monitoring the trade, including engagement with the public, pet industry, researchers and policy developers. Appropriate management strategies can also be implemented through such engagements" says Shivambu.

2 EDUCATION AND TRAINING

2.1 Under-graduate teaching

The C·I·B-run course, *BDE 345 Invasion Biology* (Stellenbosch University, 3rd year, 16 credits), was conducted online again in 2021 and was led by three C·I·B core-team members, Tammy Robinson-Smythe, John Measey and Dave Richardson. The course deals with the core aspects of invasion biology, and uses mainly South African examples to describe both problems and solutions posed by biological invasions. The course was attended by 55 students who achieved a high pass rate. Several students have enrolled for a BSc (Hons) in 2022 and have chosen to do projects with the C·I·B. The course is a substantial investment of time but is important for attracting post-graduate students.

2.2 Post-graduate training and early career researchers

During 2021 the C·I·B supported 62 students and post-docs. Details of our student and postdoc body for the year appear below.

Category	No.	%
all students & post-docs	62	100
Academic level		
Hons/4th year	2	3.23%
Masters	26	41.94%
PhD	26	41.94%
Post-doc. associates	8	12.90%
Gender		
Male	28	45.16%
Female	34	54.84%
Student demographics		
Black	28	45.16%
White	24	38.71%
Indian	1	1.61%
Coloured	9	14.52%
Asian	0	0%
Funding		
Full/Partial NRF grant	45	72.58%
Other/independent	17	27.42%
Disability		
Disabled	0	0%
Not disabled	62	100%

2.3 Career development/alumni

Our graduates continue to be in demand in many institutions nationally and internationally. The table below provides a sample of C·I·B alumni and their current positions in 2021.

Name	Degree/level	Position
Abrahams, Brent	PhD, 2021	Assistant, African Doctoral Academy
Baxter-Gilbert, James	Postdoc, 2021	Lecturer, University of Mount Allison, Canada
Botha, Lee-Ann	MSc, 2021	Research Assistant, CapeNature
Julius, Rolanda	PhD 2018	Training coordinator, University of Cape Town
Kruger, Natasha	PhD, 2020	Lecturer, University of Wolverhampton, UK
Lithole, Asiashu	MSc, 2016	Lecturer, UNISA
Mazibuko, Dickson	MSc, 2012	Lecturer, University of Malawi
Mbopha, Malukhanye	MSc, 2019	Assistant Director (Operational Support and Planning), Department of Forestry, Fisheries and the Environment (DFFE)
Mokhatla, Mohlamatsane	PhD, 2018	Senior Lecturer, University of Pretoria
Nkuna, Khensani	MSc, 2018	Intern, SANParks
Saccaggi, Davina	PhD, 2021	Research entomologist, Citrus Research International (Pty) Ltd
Shackleton, Ross	Postdoc, 2017	Researcher, Swiss Federal Institute for Forest, Snow and Landscape Research, Switzerland
Sibiya, Thabang	MSc, 2019	Scientist: SANParks
South, Josie	Postdoc, 2021	Lecturer, University of Leeds, UK
Thompson, Genevieve	PhD, 2012	Founder & CEO, Gene Vantage
Van Zitters, Monique	MSc, 2021	Intern, World Wildlife Fund (WWF)
Wagener, Carla	MSc, 2021	PhD candidate, Oxford University

3 NETWORKING

3.1 Annual Research Meeting

The C·I·B's Annual Research Meeting was held as an online event on 18-19 November 2021. The event was attended by 116 participants, with good representation among our partner organizations. There were two keynote lectures: one by core member Brian van Wilgen who spoke on "A review of the impacts of biological invasions in South Africa", the other by Hanno Seebens from the Senckenberg Biodiversity and Climate Research Centre in Frankfurt, Germany, who spoke on "Knowns and unknowns of the distribution and accumulation of alien species worldwide". The meeting was divided into four sessions, each chaired and convened by a postdoc and comprising a series of short presentations by C·I·B students. There were sessions on "Indicators, Impacts and Implications: a story of integrated restoration", "Monitoring biological invasions: where are they from, where are they going and what's happening?", "Distribution, spreading and impacts of invasive species" and "Invasion success: From monitoring to drivers". All sessions generated substantial discussion. Breakaway sessions were held to discuss issues of key concern to the C·I·B team and our partners. Travel funding prizes were awarded to the best PhD (Nicole Vorster-Martin, Stellenbosch University) and Masters (Chelsey Matthys, CPUT) presentations. These awards allow students to attend a conference or workshop. The online format of the meeting provided the opportunity for a panel discussion on "Academic contributions to practical problems with invasions – plotting a way forward". The discussion was facilitated by Chair of the C·I·B's Steering Committee Prof John Donaldson. The panel comprised Dr Andrew Turner (CapeNature), Prof. Wendy Foden (SANParks), Dr Farai Tererai (SANBI) and Mr Barney Kgope (Department of Forestry, Fisheries and the Environment).

The 2021 Annual Research Meeting also provided the opportunity for a "Virtual book launch" that involved short presentations by the authors of three books (eventually two of the titles only appeared in early 2022).

Fig. 10 Covers of three books written by C·I·B-affiliated authors scheduled for publication in 2021 (The Hui & Richardson and Measey books were both eventually only published in 2022). During the 2021 Annual Research Meeting, authors of each book presented a short overview of the contents.

3.2 Workshop on "Opportunities and limitation of using iNaturalist data"

Citizen science initiatives are gaining in popularity worldwide and are offering exciting opportunities for many aspects of invasion science. A small Covid-compliant workshop was held on 10 September 2021 at Stellenbosch University to discuss options for drawing on data from iNaturalist (and potentially other citizen science platforms) for addressing pressing questions in invasion science and Management. The workshop was led by C·I·B postdoc Christophe Botella and was attended by researchers from the Cape Peninsula University of Technology, SANBI and the University of Toronto in Canada. Several collaborative projects were proposed.

3.3 The CAPE Invasive Alien Animal Working Group (CAPE IAAWG)

Understanding and managing biological invasions requires a whole range of different skills, but often scientists and managers can feel that they are working in isolation. This is where communities of practice have been found to be useful in closing the gap between invasive species researchers and practitioners. The CAPE Invasive Alien Animal Working Group (CAPE IAAWG) is one such community of practice made up of a range of managers and scientists working on the management or control of invasive alien animals and provides a forum for them to cooperate and learn from one another and discuss issues that present difficulties or challenges. The C·I·B was a founder member of the group and several members of staff as well as core team members and students regularly attend the forum. Sarah Davies, John Measey, John Wilson, Sabrina Kumschick, Elrike Marais and numerous postgraduate students have attended regularly over the years. The forum has become a very

successful community of practice that is accessible to all those who are involved in managing invasive alien animal populations within the Cape Floristic Region.

There are many organisations in South Africa that have invasive alien species management as one of their responsibilities (or 'mandates'), such as provincial nature conservation authorities (CapeNature), protected area managers (SANParks), biosecurity authorities (DEFF) and NGOs such as the Society of the Prevention of Cruelty to Animals (SPCA), which is charged with ensuring that animals are not mistreated. In addition, many universities and research organisations conduct research on invasive alien animals. The working group brings these role-players together two or three times a year to discuss ongoing projects and emerging issues. The geographical scope of the group is largely defined by the CFR, which includes most of the Western Cape and the western part of the Eastern Cape. In addition to being a forum for learning and discussion, the group aims to enhance cooperation among stakeholders such as implementing agencies and researchers, and thereby improve the management of invasive animals in the Greater Cape Floristic Region. The groups also serves as a forum for C·I·B students to engage with managers and researchers and to present preliminary results of their research and seek inputs.

3.4 Agreements with partner institutions

The C·I·B has Memoranda of Understanding with several organisations who work in the biodiversity conservation fields. These have multiple benefits for the C·I·B, adding to our perspectives on the environmental, economic and social impacts of invasive species, and helping us in engaging with the diverse communities who are affected.

Table. Memoranda of Understanding with partner organisations

Partner organisation	Contact person(s)	Partnership since
Western Cape Education Department	Jean Goliath	2006
DEFF: Natural Resources Management	Andrew Wannenburgh	2008
CapeNature	Andrew Turner	2006
City of Cape Town	Julia Wood	2012
Centre for Statistics in Ecology, the Environment and Conservation, University of Cape Town	Res Altwegg	2016
BirdLife South Africa	Hanneline Smit-Robinson	2014
The Nature Conservancy, South Africa	Louise Stafford	2018
Institute of Botany, Academy of Sciences of the Czech Republic	Petr Pyšek	2013
Laboratorio de Invasiones Biológicas, Universidad de Concepción, Chile	Aníbal Pauchard	2013
Other memberships essential to our mission:		
CAPE Invasive Alien Animals Working Group	Julia Wood, CoCT / Andrew Turner, CapeNature	2008
Soil Ecosystem Research Group	Charlene Janion-Scheepers, UCT	2011
The Honolulu Challenge	Kevin Smith	2016

4 INFORMATION BROKERAGE

4.1 Iimbovane Outreach Project

The most obvious important highlight of 2021 for the Iimbovane team was their return to the classroom in person. After a year without any practical work, both the Iimbovane team and learners were thrilled to get outside for practical fieldwork.

Classroom lessons

Despite direct school-based engagements remaining constrained due to Covid-19 restrictions, an adapted school curriculum and rotational teaching schedules, the Iimbovane project team managed to conduct 41 school-based lessons at Iimbovane partner schools. These lessons included theory as well as fieldwork that enabled participating learners to develop basic practical scientific skills. The Iimbovane Project trained **841 high school learners** through these lessons in 2021. These lessons are curriculum-linked and include resources that educators can use in their classroom teaching.

Life Science educator, Mr Dwashu at Diazville High School in Saldanha, who was working with Iimbovane for the first time highlighted the value of the practical component of Iimbovane and how educators and learners benefit from it. He commented: "*The Iimbovane Project is beneficial to Grade 10 learners as it ties in with the topic of biodiversity. It essentially shows biodiversity in action. Learners can be assessed on this topic by inserting it as a case study in an assignment or test or exam paper. It is also helpful in explaining the topic of classification as learners learn valuable skills of using scientific keys to identify ants, which can also be assessed in an assignment, test or exam*."

An Afternoon with Ants

In Nov 2021, Iimbovane collaborated with the Iziko South African Museum in hosting two educator workshops, titled *An Afternoon with Ants*. These workshops took place at the Museum's new Biodiversity Laboratory, giving the attendees the opportunity to use the lab's high-quality microscopes. The workshops were attended curriculum planners and educators from the Western Cape Education Department (WCED), environmental educators from Contour Enviro Group, the Wildlife and Environment Society of South Africa (WESSA), Iziko South African Museum and Cape Nature. Feedback indicated that these workshops were successful in increasing educators' enthusiasm and capacity in teaching the topic of biological classification at the Grade 7 and Grade 10 school level. Having focused on Grade 10 learners from its inception, Iimbovane not only helped train primary school educators at An Afternoon with Ants events but will include these educators and their Grade 7 learners increasingly in future.

"*Classification is a challenging concept in the Grade 7 curriculum. The workshop demystified the concept and process of classification by using ant species. It can be useful to educators and learners and can be used for practical assignments and as part of formal assessments*." – Suanne Rampou, WCED Deputy Chief Education Specialist: Natural Sciences.

Collaborative learner workshops

Getting learners to explore biodiversity in a hands-on fashion is one of Iimbovane's core principles. In 2021, Iimbovane had the privilege of hosting five learner workshops in collaboration with partners from its education network, including Nature Connect, SANBI, SANParks, Contour Enviro Group and the Cape Leopard Trust. A total of **118 learners** were trained during these workshops.

Assisting taxonomists

Another highlight of 2021 is Iimbovane's collaboration on a project that is reviewing an important ant group. Iimbovane's role in the project is the contribution of ant specimens from the *Anoplolepis* group that were collected by learners who participated in Iimbovane between 2006 and 2014. These specimens are being barcoded, and the resulting molecular data will help to confirm species identifications and will lead to an updated identification key to the genus *Anoplolepis*.

Iimbovane also provided researchers on the project with a platform to share their expertise and findings with the public. In doing so, taxonomist Abusisiwe Ndaba, who is currently completing her MSc on *Anoplolepis*, assisted the Iimbovane team in presenting classroom lessons during the team's school visits and workshops.

> "*There is a need for taxonomists to encourage the public to learn about local ant communities and to be aware of the diversity of ants around them. Iimbovane gave me the perfect platform and I enjoyed sharing my knowledge about ants with the Iimbovane learners."* – Ms Abusisiwe Ndaba (MSc student based at Iziko South African Museum).

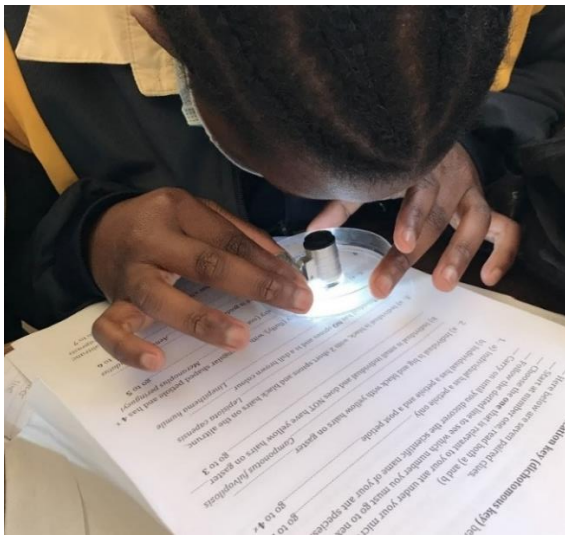


Fig. 11 A Grade 10 learner from Luhlaza Secondary School in Khayelitsha learning basic scientific skills – using a microscope and a scientific key.

Fig. 12 Ms Abusisiwe Ndaba, an MSc student based at the Iziko South African Museum, shows a learner how to identify an ant species during an Iimbovane classroom lesson.

Fig. 13 & Fig. 14 Learners learning valuable practical scientific skills while conducting biodiversity surveys in their school grounds.

Fig. 15 Educators attending “An Afternoon with Ants” workshop were treated to using the high-quality microscopes in The Biodiversity Laboratory of the Iziko South African Museum.

4.2 Communication with the public

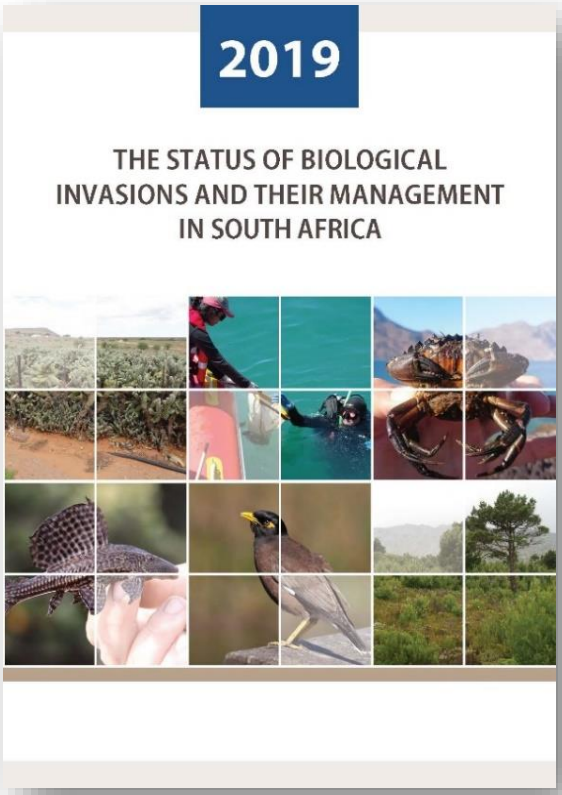
Media highlights

The contribution of C·I·B researchers to South Africa’s second national report on biological invasions received wide attention in the media. The report, titled “*Status of Biological Invasions and their Management in South Africa*" provides a comprehensive assessment of the status of invaders and is the only country-level assessment worldwide that focuses specifically on biological invasions. The

launch of the report by Minister of Forestry, Fisheries and the Environment, Barbara Creecy, led to articles in newspapers such as the *Mail & Guardian* and *Cape Argus*. The report was further publicised through articles on online news sites such as *Engineering News, News24, Xinhuanet News, All Africa, Daily Maverick, Suid-Kaap Forum* and *The North Coast Courier*.

In August 2021, a paper by C·I·B core team member Susana Clusella-Trullas in the journal *Trends in Ecology and Evolution* resulted in articles on both local and international media platforms. In the paper, Clusella-Trullas and her team propose how the current, widely adopted thermal vulnerability index, can be improved. These findings are an important step in improving our understanding how animals respond to climate change and led to articles in publications including *Landbouweekblad* and *Mail & Guardian*. Further articles about the paper appeared on online news sites including *Science Daily* and *Independent Online*.

An interview with C·I·B core team member John Measey about animals under threat from alien pine trees generated articles in the local and international media. Articles appeared in newspapers including the *Cape Times, Cape Argus, Daily Express* and *Kingston Whig-Standard* (Canada). The article was further publicized through online news sites such as *Engineering News, Reuters, EuroNews* and *Texas News Today*.



C·I·B core team member Tammy Robinson-Smythe and post-doc Tainã Gonçalves Loureiro received much media attention following their publication in *African Journal of Marine Science*. Their paper, which describes a new method for monitoring marine invasive species, featured on several online platforms including *All Africa, Marine Technology News, Eyewitness News, Phys.org, The Conversation, Daily Maverick* and *Modern Ghana*.

See Appendix 2 for a full list of media interactions.

4.3 Web-based services and social media

Zenodo	https://zenodo.org/communities/cib
In January 2021 the C·I·B management team decided to migrate all existing C·I·B datasets from the institutional repository hosted by SU to the online and open access portal Zenodo. By June 2021 all existing datasets had C·I·B been migrated to Zenodo.	
Web page	https://blogs.sun.ac.za/cib
18 059 unique visitors **26 062** unique page views Most visitors were from Africa, North America and Europe.	
Facebook	https://www.facebook.com/centreforinvasionbiology
1755 followers | **1711** like this page **46** posts | **312** viewers per post (average) Most popular posts:	
Twitter	@invasionscience
67 total Tweets | **1624** followers Per day average: **242** impressions | **49** link clicks | **17** retweets | **36** likes | **2** replies **Top Tweet:** How do researchers think about policymakers? [8632 impressions]	

Date	*C·I·B nugget*	*People reached*
9 Nov	*Get out of my swamp – chasing crayfish in the Zambezi Basin*	811
2 Aug	*Volunteers in the management of invasive alien plants*	689
13 Dec	*Mountain roads as conduits for ongoing exotic species expansion*	605
1 Feb	*The status of alien bamboos in South Africa*	504

5 SERVICE PROVISION

5.1 The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem (IPBES)

IPBES is an independent intergovernmental body that was established in 2012 and currently has 137 members. Often described as the 'IPCC for biodiversity', IPBES aims to strengthen knowledge foundations for better policy through science, for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development. IPBES has undertaken assessment a wide range of specific themes of global importance relating to biodiversity and

ecosystem Services. Completed assessments have included “Pollinators, pollination and food Production” (2016); “Land degradation and restoration” (2018); “Sustainable use of wild species” (2021). There have also been assessments on methodological issues [“Scenarios and models” (2016); “Values” (2021)] and regional and global-level overviews [Regional assessments of Biodiversity and Ecosystem Services (2018)]. The “Global assessment of biodiversity and ecosystem services (2019). has been instrumental highlighting the dire status of biodiversity and global declines. Due to the rapidly increasing threat by invasive alien species and the urgent need for international cooperation, IPBES began a thematic assessment on thematic assessment of invasive alien species and their control in 2019. This assessment, scheduled for completion in 2022 aims to assess the threat that invasive alien species pose to biodiversity, ecosystem services and livelihoods and the global status of and trends in impacts of invasive alien species by region and sub-region, taking into account various knowledge and value systems.

The C·I·B is involved in the IPBES assessment in several ways. Several C·I·B core team members are (or were) involved as Lead Authors of chapters: Llewellyn Foxcroft, Sebataolo Rahlao (Coordinating Lead Author) and Olaf Weyl (until his death in November 2020). C·I·B core team members Dave Richardson and John Wilson are Review Editors. C·I·B associates Ryan Blanchard and Petr Pyšek are Lead Authors, C·I·B international scientific advisor Laura Meyerson is a Coordinating Lead Author, and a former PhD student Maria Loreto Castillo is one of 12 IPBES fellows. C·I·B team members have also been consulted in various other ways.

5.2 EICAT & SEICAT

The Environmental Impact Classification for Alien Taxa (EICAT) is the IUCN’s standard for assessing impacts of alien species. The C·I·B is involved in several activities around EICAT: a) C·I·B core team member Sabrina Kumschick established and is current chair of the EICAT Authority which reviews EICAT assessments before they are published on the Global Invasive Species Database (GISD) website to ensure quality standards are met; b) several C·I·B core team members and students have contributed EICAT assessments to the GISD; this will be the most comprehensive global database on impacts of alien species, and is compiled in a transparent and standardised manner.

Regular EICAT Authority online meetings were chaired by Sabrina Kumschick in 2021 to discuss operational issues around EICAT, as well as the development of guidelines, templates, training materials, and assessments. 97 species assessments have been reviewed and accepted for publication to date; these will soon appear on the GISD website.

The C·I·B has, through various projects, developed EICAT assessments, either for student theses or for collaborative research projects. These assessments are all transferred to the IUCN’s standard template and submitted to the EICAT Authority for review and publication on the GISD website.

The Socio-economic Impact Classification of Alien Taxa (SEICAT) is a framework to assess socioeconomic impact of alien taxa on human well-being in a transparent and evidence-based manner. The main aim of SEICAT is to provide a framework in which all impacts on human well-being can be captured. This framework was co-developed by several C·I·B members and international colleagues. The framework will eventually be used to develop a database of impacts of alien species on human well-being.

The SEICAT framework was published in the scientific literature (with several C·I·B authors), and additional guidance documents are being prepared and developed. Several applications of the framework have also been published, some by C·I·B core team members, associates and students.

SEICAT aids policy makers, nature conservation practitioners, scientists and alien species managers to prioritise species for regulation, management, and study by providing a transparent, evidence-based classification of alien species impacts. This can improve the way alien species are managed.

5.3 The Alien Species Risk Analysis Review Panel (ASRARP)

ASRARP is a panel of experts co-ordinated by the South African National Biodiversity Institute [SANBI]). The main objectives of ASRARP are: a) to make independent and informed recommendations on applications for imports of new alien species to the Republic to the Department of Forestry, Fisheries and the Environment (DFFE); b) review risk analyses for the listing of alien species under the NEM:BA Alien and Invasive Species Regulations; and to c) review risk analysis guidelines. Seven the 25 ASRARP members are C·I·B affiliates: four core team members (Sabrina Kumschick, Sheunesu Ruwanza, John Wilson, Brian van Wilgen) and three associates (Sjirk Geerts, Ryan Blanchard, Mlungele Nsikani).

Quarterly online meetings were held in 2021 to discuss risk analyses for species listed under the NEM:BA Alien and Invasive Species Regulations as well as risk assessments for the import of new alien species submitted to the DFFE. All risk analyses are handled by an ASRARP member, including some C·I·B core team members and associates, and reviewed by external experts. ASRARP members prepare a review report for the risk assessors. Once approved, risk analyses and recommendations are submitted to DFFE via SANBI, who reviews the recommendations and makes decision regarding import permits and/or listing of alien species.

The main engagement partners are the SANBI who is providing the secretariat to the panel, the risk assessors, and the DFFE, and panel members from many organisations. Highlights are that the ASRARP was operational throughout lockdown despite organisational challenges. Many important milestones have been reached within the umbrella of the ASRARP, including the publication of the risk analysis framework for underpinning the NEM:BA Alien and Invasive Species Regulations listings in 2020, with C·I·B core team member Sabrina Kumschick as lead author, and the submission of many recommendations for listing and risk analyses to the DFFE. Regular meetings between DFFE and

SANBI (involving the C·I·B representative through the C·I·B-SANBI collaboration agreement) ensure the relevance of the work of ASRARPs and the C·I·B work to DFFE. Feedback from ASRARP also lead to new students projects and collaboration with partners.

ASRARP ensures that quality standards are followed for risk analysis underpinning the listing of alien species under the NEM:BA Alien and Invasive Species Regulations, and that the evidence provided therein is sound and relevant. These risk analyses will eventually be published on the DFFE website and become available to all stakeholders. They will be an important resource for the justification of listing of alien species.

5.4 Panels and committees

5.4.1 International

African Arachnological Society: Chairman (Foord)
African Institute for Mathematical Sciences (AIMS): Researcher (Hui)
EICAT Authority: Chair (Kumschick)
GEO BON Species Populations Working Group: Member (Wilson)
IITE (International Initiative for Theoretical Ecology), Trustee (Hui)

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) – Invasive Alien Species Assessment: Lead Author (Foxcroft); Coordinating Lead Author (Rahlao); Contributing Author (Richardson); Review Editor (Hui; Richardson; Wilson); Technical Advisor (Wilson)
International Ornithological Congress: Fellow (Downs)

Invasive Organism Observation Information Charter: A Task Group of Biodiversity Data Quality Interest Group. Biodiversity Information Standards (TDWG): Member (Wilson)

IUCN Academy – Academic Partner (Esler)

IUCN Species Survival Commission (SSC)- Afrotheria specialist Group: Member (Downs)

IUCN SSC - Amphibian Specialist Group: Member (Measey)

IUCN SSC - Conifers: Member (Richardson)

IUCN SSC - Crocodile Specialist Group: Member (Downs)

IUCN SSC - Hippo Specialist Group: Member (Downs)

IUCN SSC - Invasive Species Specialist Group: Member (Kumschick; Richardson; van Wilgen; Wilson)

IUCN-SSC - Otter Specialist Group: Member and Southern African Coordinator (Somers)

IUCN-SSC – Ladybird Specialist Group: Member (Clusella-Trullas)

IUCN-SSC - Re-introduction Specialist Group: Member (Somers)

IUCN-SSC - Small Carnivore Specialist Group: Member (Somers)

IUCN SSC - Stork Specialist Group: Member (Downs)

IUCN SSC - Spiders and Scorpion Specialist Group: Member (Foord)

IUCN-SSC - Wild Pig Specialist Group: Member (Somers)

LIFE CROAA: Commission Européenne dans le cadre du programme européen LIFE: Member (Measey)

Marine Bioinvasions, International Conference on, Scientific Steering Committee member (Robinson-Smythe)

MEDECOS Association, Executive committee of ISOMED: National Representative (Esler)

5.4.2 National

Alien Species Risk Analysis Review Panel (ASRARP): Member (Kumschick, Ruwanza, van Wilgen);

Chair then Secretary (Wilson)

CAPE Invasive Alien Animals Working Group: Member (Davies; Kumschick; Measey; Wilson)

Cape Peninsula University of Technology Review Panel, Conservation and Marine Sciences (Esler)

Centre for Sustainability Transitions, Stellenbosch University: Governing Board Member (Esler)

Fynbos Forum Custodian Member: (Esler)

Entomological Society of South Africa: Vice President (Foord)

IUCN Wild Dog Advisory Group of South Africa: Member (Somers)

Polyphagous shot hole beetle Steering Committee, Department of Agriculture, Land Reform and Rural Development. Member (Foxcroft; Richardson)

SANBI Board member [Chair of Research, Development and Innovation Subcommittee] (Van Wilgen)

5.5 Editorial and refereeing activities

5.5.1 Editor-in-Chief / Editor / Thematic/Regional Editor

Conservation Biology, Regional Editor Africa (Esler)

5.5.2 Associate Editor

African Journal of Ecology (Downs)

African Journal of Wildlife Research (Somers)

Aquatic Invasions (Robinson-Smythe; Zengeya)

Austral Entomology (Terblanche)

BioInvasions Records (Measey; Robinson-Smythe; Zengeya)

Biological Invasions (Hui; Kumschick; Richardson)

Ecological Complexity (Hui)

Ecological Solutions and Evidence (Zengeya)

Ecography (Clusella-Trullas)

F1000 (Terblanche)

Forest Ecosystems (Richardson)

Frontiers in Ecology and Evolution (Hui)

Global Ecology and Biogeography (Hui)

Herpetological Conservation & Biology (Measey)

Ibis (Downs)

Koedoe (Foord; Robinson-Smythe)

Mammalian Biology (Somers)

NeoBiota (Foxcroft; Kumschick; Richardson; Wilson)

PeerJ (Measey)

Salamandra (Measey)

Urban Ecosystems (Downs)

5.5.3 Editorial Boards

African Entomology (Terblanche)

AoB PLANTS (Richardson)

Cambridge University Press *Ecology, Biodiversity and Conservation* book series (Richardson)

Current Research in Insect Science (Terblanche)

Fire Ecology (van Wilgen)

Journal of Experimental Biology (Clusella-Trullas)

Journal of Insect Physiology (Terblanche)

Journal of Thermal Biology (Clusella-Trullas; Terblanche)

Koedoe (Foxcroft; Somers)

Nature Conservation Research (Somers)

Ostrich (Downs)

PCI Zool https://zool.peercommunityin.org ("Recommender": Measey)

Zookeys (Foord)

6 GOVERNANCE AND ORGANIZATIONAL STRUCTURE

6.1 Steering Committee

Name	Affiliation	Role
Prof. John Donaldson	Independent consultant	Chair
Prof. Eugene Cloete	Vice-rector, research development, Innovation and postgraduate studies, Stellenbosch University	Ex-officio member
Prof. Louise Warnich	Dean, Faculty of Science, Stellenbosch University	Ex-officio member
Prof. Dave Richardson	Director, Centre for Invasion Biology, Stellenbosch University	Ex-officio member
Dr Sarah Davies*	Deputy-Director, Operations, Centre for Invasion Biology, Stellenbosch University	Ex-officio member
Prof. John Measey	Deputy-Director, Research Strategy, Centre for Invasion Biology, Stellenbosch University	Ex-officio member
Dr Makobetsa Khati	Executive Director (RCCE), National Research Foundation	NRF representative
Mr Nathan Sassman	Director, Research Chairs and Centres of Excellence (RCCE), National Research Foundation	NRF representative
Ms Rose Msiza	Director, Research Support, Department of Science & Innovation	DSI representative
Mr Leluma Matooane	Director, Earth Systems Science, Department of Science & Innovation	DSI representative
Prof. Michael Somers	Eugène Marais Chair of Wildlife Management, Mammal Research Institute, University of Pretoria	C·I·B core team representative
Dr Angus Paterson	Managing Director, South African Institute for Aquatic Biodiversity	Industry Representative
Mr Michael Braack	Director, Biosecurity, Natural Resource Management Programme, Department of Environment, Forestry and Fisheries	Industry Representative
(vacant)	Biodiversity Management Programme, South African National Biodiversity Institute	Industry Representative
Prof. Sheona Shackleton	Deputy Director, African Climate and Development Initiative (ACDI), University of Cape Town	Industry Representative
Prof. Piero Genovesi	Director, ISPRA Institute for Environmental Protection and Research, Italy	International Science Advisor
Prof. Laura Meyerson	Professor, Department of Natural Resources Science, The University of Rhode Island, USA	International Science Advisor

*Left the C·I·B 31 March 2021

6.2 Personnel involved in the CoE

6.2.1 C·I·B core team members

Name	Institution	Race	Gender	Citizenship	% time @ C·I·B	NRF rating
Byrne, Marcus, Prof.	Wits	W	M	RSA	30%	C
Chimimba, Chris, Prof.	UP	B	M	RSA	25%	C
Clusella-Trullas, Dr Susana	SU	W	F	RSA	20%	C
Downs, Colleen, Prof.	UKZN	W	F	RSA	10%	C
Esler, Karen, Prof.	SU	W	F	RSA	10%	C
Foord, Stefan, Prof.	UniVen	W	M	RSA	5%	C
Foxcroft, Llewellyn, Prof.	SANParks	W	M	RSA	15%	C
Hui, Cang, Prof.	SU	A	M	RSA	10%	B
Kumschick, Sabrina, Dr	SU	W	F	Switzerland	90%	C
Measey, John, Prof.	SU	W	M	UK	95%	C
Mokotjomela, Thabiso, Dr	SANBI	B	M	RSA	20%	Not rated
Rahlao, Sebataolo, Dr	EKZNW	B	M	RSA	5%	Not rated
Richardson, David, Prof.	SU	W	M	RSA	100%	A
Robertson, Mark, Prof.	UP	W	M	RSA	30%	C
Robinson-Smythe, Tammy, Prof.	SU	W	F	RSA	35%	C
Ruwanza, Sheunesu, Dr	RU	B	M	RSA	20%	Not rated
Somers, Michael, Prof.	UP	W	M	RSA	10%	C
Terblanche, John, Prof.	SU	W	M	RSA	15%	B
Van Wilgen, Brian, Prof.	SU	W	M	RSA	25%	B
Wilson, John, Prof.	SU	W	M	RSA	80%	B
Zengeya, Tsungai, Dr	SANBI	B	M	RSA	40%	Y

Emeritus Prof. Charles Griffiths resigned his core team membership 31 December 2020.

6.2.2 C·I·B research associates

Name	Affiliation
Alexander, Mhairi, Dr	University of West Scotland, UK (animal behaviour ecologist)
Blackburn, Tim, Prof.	Chair of Invasion Biology at Centre for Biodiversity and Environment Research in Department of Genetics, Evolution & Environment, University College London, UK (bird ecologist)
Blanchard, Ryan, Dr	Biodiversity and Ecosystems Services research group, Natural Resources and the Environment, CSIR (plant ecology)
Davies, Sarah, Dr	Free-lance ecologist (biodiversity scientist, conservation ecologist)

Essl, Franz, Prof.	Austrian Environment Agency; University of Vienna, Austria (plant ecologist)
Gaertner, Mirijam, Prof.	Environmental Sciences programme head, Nürtingen-Geislingen University of Applied Science, Germany (restoration ecologist)
Geerts, Sjirk, Prof.	Cape Peninsula University of Technology (plant ecologist)
Giliomee, Jan, Prof.	Emeritus Professor, Stellenbosch University (entomology)
Holmes, Patricia, Prof.	Extraordinary Professor, Department of Conservation and Entomology, Stellenbosch University (restoration ecologist)
Jackson, Michelle, Dr	Department of Zoology, University of Oxford, UK (freshwater ecologist)
Janion-Scheepers, Charlene, Dr	Department of Biological Sciences, University of Cape Town (entomologist)
Jordaan, Martine, Dr	Scientific Services, CapeNature (aquatic ecology)
Kueffer, Christoph, Prof.	Department of Environmental Systems Science, ETH Zurich, Switzerland (plant ecologist)
Le Maitre, David, Prof.	Extraordinary Professor, Department of Conservation and Entomology, Stellenbosch University (plant ecologist and hydrologist)
Le Roux, Jaco, Prof.	Department of Biological Sciences, Macquarie University, Australia (plant ecologist)
Nsikani, Mlungele, Dr	South African National Biodiversity Institute (restoration ecologist)
Pepler, Dave	Free-lance media expert (media)
Pyšek, Petr, Prof.	Department of Invasion Ecology, Institute of Botany, Academy of Sciences of the Czech Republic (plant ecologist)
Ricciardi, Anthony, Prof.	Redpath Museum & School of Environment, McGill University, Canada (freshwater ecologist)
Shackleton, Ross, Dr	Swiss Federal Institute for Forest, Snow and Landscape Research, Switzerland (plant ecologist)
South, Josie, Dr	University of Leeds, UK (freshwater ecologist)
Van Wilgen, Nicola, Dr	SANParks Scientific Services, Cape Cluster (animal ecologist)
Woodford, Darragh, Dr	School of Animal, Plant and Environmental, University of the Witwatersrand (freshwater ecologist)

Prof. Jane Carruthers, formerly of UNISA, resigned her research associateship 31 December 2020.

6.2.3 C·I·B staff

Name	Position	Race	Gender
Coombe-Davis, Karla, Ms*	Database manager	W	F
Davies, Sarah, Dr*	Deputy Director: Operations	W	F
Du Plessis, Dorette, Ms	Iimbovane Outreach Programme manager	W	F
Kritzinger-Klopper, Suzaan, Ms	Chief technical officer	W	F
Kumschick, Sabrina, Dr	Researcher	W	F
Marais, Elrike, Dr	Research & project manager	W	F
Measey, John, Prof.	Deputy Director: Research Strategy	W	M
Momberg, Christy, Mrs	Management administrator	W	F
Msomi, Londiwe, Ms	Education outreach officer	B	F
Nortje, Erika, Ms	Ecophysiology lab manager	W	F
Richardson, Dave, Prof.	Director	W	M
Van der Vyfer, Mathilda, Ms	Administrative officer	W	F
Van Wilgen, Brian, Prof.*	Research professor	W	M

*Ms Coombe-Davis resigned her C·I·B post effective 31 August, 2021. Dr Davies resigned her C·I·B position effective 31 March 2021. Ms Van der Vyver resigned her C·I·B post effective 30 April 2021. Prof. Van Wilgen resigned his staff role in October 2021 (but retains his role as senior researcher).

6.2.4 C·I·B Management Committee

Name	Affiliation
Measey, John, Prof.	C·I·B Deputy Director: Research Strategy
Richardson, Dave, Prof. (Chair)	C·I·B Director
Somers, Michael, Prof.	University of Pretoria
Zengeya, Tsungai, Dr	South African National Biodiversity Institute

C·I·B management administrator Christy Momberg is the scribe.

6.2.5 C·I·B Scientific Advisory Committee

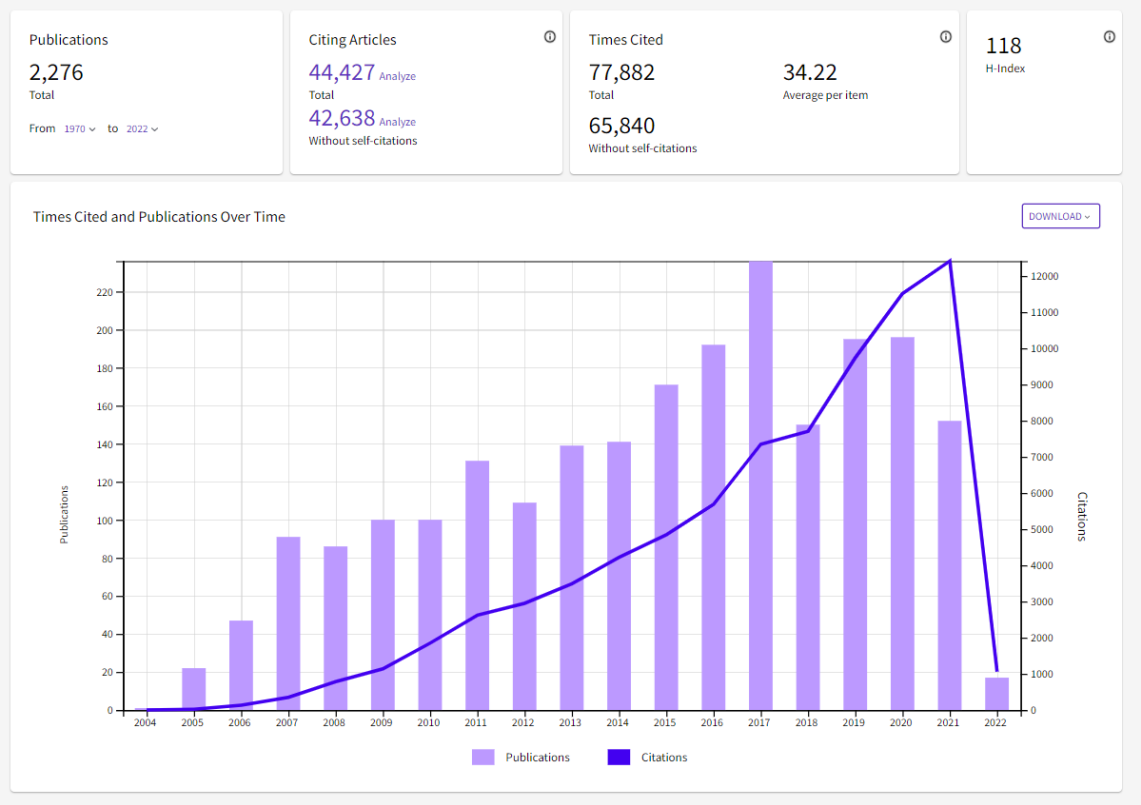
Name	Affiliation
Genovesi, Piero, Dr	Chair, IUCN Invasive Species Specialist Group
Measey, John, Prof.	C·I·B Deputy Director: Research Strategy
Meyerson, Laura, Prof.	University of Rhode Island, USA
Richardson, Dave, Prof.	C·I·B Director
Slingsby, Jasper, Dr	University of Cape Town
Zengeya, Tsungai, Dr	South African National Biodiversity Institute

See Appendix 3 for details of C·I·B post-docs and students.

7 RETURN ON RESEARCH INVESTMENT

The C·I·B published 142 papers in peer-reviewed journals in 2021. This is a major return on investment for South Africa (funding from DSI was R5m, yielding R35.2k per publication unit).

Citation impact



Citation report for the C·I·B (2004-2020). Downloaded 23 February 2021. Data for 2022 reflect citations for less than 2 months of the year.

http://apps.webofknowledge.com.

8 PROGRESS AGAINST SLA TARGETS

The C·I·B operated under Service Level Agreement No. 7 (2020-2022) during 2021, with the following targets, deliverables and results:

8.1 Governance

Two Steering Committee (virtual or real) meetings should take place per annum	2021 target was Feb & Oct/Nov	25 March; & 22 November 2021	100%
Student nominations submitted to the NRF's student database	2021 target = by deadline determined by the NRF	Deadline met	100%
Annual Progress Reporting on all activities undertaken during the year for review by the Steering Committee	Target = End Feb of following year	NRF Online APR submitted 15FEB & narrative APR to SteerCom 23 March 2022	100%

8.2 Research outputs

Peer-reviewed research papers published	2021 target = 75	142	190%
Peer-reviewed papers with IF > 15 published	Target = 2/pa	0	2 close*
Peer-reviewed papers with IF > 4 published	Target = 20	25	+5

*The C·I·B had publications in *Nature Communications* (~14.9 IF) and *Science Advances* (~14.1 IF).

8.3 Education and training

Student registrations supported by the centre with either full, partial or independent funding	*2021 target was 15*	54	360%
Honours students graduated	*Target = 2*	1	50%
Masters students graduated	*Target = 8*	5	63%
PhD students graduated	*Target = 8*	3	Several PhDs delayed by Covid
Post-docs completed	*Target = 2*	2	100%
Female students supported	*Target = 55%*	57%	exceeded
Black students supported	*Target = 90%*	63%	short
SA students citizens & permanent residents, of which Black 90%, White 10%, Disabled 1%	*Target = 95%*	87%	short
Post-docs or early-career researchers as proportion of supported researchers	*Target = 10% pa*	11%	exceeded

8.4 Networking

The CoE will publish vignettes of information on its website and provide these to the NRF	*2021 target = biannual delivery to NRF*	42 vignettes were published on the C·I·B website, and further publicized via Facebook, Twitter. Vignettes remitted to NRF on 2 July 2021 & 11 January 2022.
Co-host SARChI Chair in Biodiversity Value and Change in the Vhembe Biosphere Reserve	*Ostensibly phased out in 2020*	The UniVen SARChi Chair and lab have become the C·I·B's new Northern Hub

Memoranda of Understanding with key regional, national and international partners	*Maintain under appropriate branding*	Maintaining & creating additional MoUs	100%
Joint supervision of students outside the core team and at other universities	*2021 target was 2*	29	exceeded
Maintain a network of actively engaged Research Associates	*5-10 Research Associate-led papers per year*	7	On target
National conference attendance	*2021 target = 5*	29	580%
International conference attendance	*2021 target = 5*	15	300%
National conference/workshop organization	*2021 target = 0*	0	N/A
International conference/workshop organized	*2021 target = 0*	1	exceeded

8.5 Information brokerage and outreach

Maintain an Information Retrieval and Submission System (IRSS) that curates the outputs of the Centre	*2021 target was IRSS converted to open source data*	The C·I·B segment of the Zenodo platform went live, and all existing datasets were migrated in 2021.
Social media engagements with partners and interested parties (DSI-NRF branding)	*Phased out*	Active profiles on social media (Facebook, Twitter) &l the C·I·B's website.
Iimbovane outreach activities continue in 20 schools	*2021 target = 10 schools*	Iimbovane held training activities in 11 schools.
Classroom and field-based lessons presented at schools	*target = 25 lessons*	Delivered 41 field-based and classroom lessons at Iimbovane partner schools.
Number of learners participating in the Iimbovane Outreach Project	*target = 400 learners*	841 learners participated in Iimbovane during school-based activities and lessons. Iimbovane trained a further 118 learners through learner workshops. Delivered 240% of target

News interest in both print and online media	*target = 10*	64	640%
Popular articles and talks in both print and online media	*2021 target = 5*	10	200%

8.6 Service provision

Rating and scientific reviews for the NRF	*2021 target was 5*	40 reviews	Exceeded target
Peer evaluations for national and international grant-making bodies	*target = 5*	6	exceeded
Participation in international science organizations	*target = 10*	46	exceeded
Journal editorships (editor, associate editor or editorial board membership)	*target = 10*	35	exceeded
Reviewing activities for national and international journals.	*target = 10*	90	exceeded
Inputs to policy relevant processes and documents	*target = 1*	NSR & ASRARP	exceeded

9 CONCLUSION

Despite challenges on many fronts, the C·I·B has demonstrated an impressive return on investment, meeting or exceeding almost all Service Level Agreement targets. The C·I·B is well positioned to fulfil its mandate as a national Centre of Excellence until the end of its association with DSI and NRF at the end of March 2023.

Good progress is being made towards reinventing the C·I·B for life after DSI/NRF as a component and partner of Stellenbosch University's School for Climate Studies.

APPENDICES

APPENDIX 1- PUBLICATION OUTPUTS

Peer-reviewed publications

Abutaleb, K., Newete, S.W., Mangwanya, S., Adam, E. & Byrne, M.J. (2021). Mapping eucalypts trees using high resolution multispectral images: A study comparing WorldView 2 vs. SPOT 7. *Egyptian Journal of Remote Sensing and Space Science* **24**, 333-342. https://doi.org/10.1016/j.ejrs.2020.09.001.

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APPENDIX 2- MEDIA OUTPUTS

Newspapers (print)

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APPENDIX 3- SUPPORTED POST-DOCS AND STUDENTS

C·I·B post-doctoral fellows

Name	Citizenship	Institution	Race	Gender	Status	Funding
Baxter-Gilbert, J.	Canada	SU	W	M	Completed	Full
Botella, Christophe	France	SU	W	M	Continuing	Independent
Hirsch, H.	Germany	SU	W	F	Completed	Full
Keet, J-H.	RSA	SU	W	M	Completed	Full
Loureiro, T.G.	Brazil	SU	L	F	Completed	Full
Melotto, Andrea	Italy	SU	W	M	Continuing	Independent
South, Josie	UK	SAIAB	W	F	Completed	Full

C·I·B students supported by the Centre in 2021

Name	Citizenship	Institution	Race	Gender	Status	Funding
BSc (Honours)/4th year B. Agric.						
Angus, Oliver	RSA	SU	W	M	Completed	Independent
MSc/Masters						
Afonso, Luca	RSA	SU	W	M	Completed	Partial
Bhikraj, Kiosha	RSA	UKZN	I	F	Completed	Full
Boast, Kyle	RSA	SU	W	M	Completed	Independent
Botha, Lee-Anne	RSA	UP	C	F	Completed	Full
Carelse, Gaylen	RSA	SU	C	F	Continuing	Partial
Collop, Amy	RSA	SU	C	F	Completed	Full
Du Plessis, Aneesa	RSA	CPUT	C	F	Continuing	Full
Engelbrecht, Armand	RSA	UP	W	M	Continuing	Partial (+HCID direct)
Homani, Aviwe	RSA	SU	B	F	Dismissed	Full
Kharivha, Tshililo	RSA	RU	B	M	Completed	Full
Lehman, Tevan W.K.	RSA	SU	W	M	Completed	Independent
Mahlobo, Thandeka	RSA	UKZN	B	F	Completing	Full
Mantintsilili, Asekho	RSA	UKZN	B	M	Completed	Full
Matam, Ncumisa	RSA	RU	B	F	Completed	Partial
Matthys, Chelsey	RSA	CPUT	C	F	Continuing	Independent
Msweli, Lindelwa	RSA	UKZN	B	F	Completed	Partial
Ntuli, Nkosinathi	RSA	NMU	B	M	resigned	Full
Peta, Samuel T.P.	RSA	SU	B	M	Completed	Full
Pienaar, Madeleine	RSA	SU	W	F	Continuing	Full
Qikwa, Asive	RSA	SU	B	M	Resigned	Independent
Seboko, Tshepiso	RSA	RU	B	N	Completed	Full
Thwala, Thembeka	RSA	UniVen	B	F	Resigned	Independent

Van Blerk, Dan	RSA	SU	W	M	Continuing	Independent
Van Zitters, Monique	RSA	SU	W	F	Completed	Partial
Visagie, Marizanne	RSA	SU	W	F	Continuing	Independent
PhD						
Abrahams, Brent	RSA	SU	C	M	Completed	Full
Araspin, Laurie	France	SU	W	F	Continuing	Partial
Bolosha, Uviwe	RSA	RU	B	F	Continuing	Full
Bosua, Henrika	RSA	SU	W	F	Continuing	Full
Duncan, Patricia	RSA	SU	W	F	Continuing	Partial
Jones, Emily	RSA	NMU	W	F	Completed	Full
Maimela, Lerato T.	RSA	UP	B	F	Continuing	Partial
Malingana-Shivambu, N.	RSA	UKZN	B	F	Completed	Partial
Mapaura, Anthony	Zimbabwe	UFS	B	M	Continuing	Partial
Matikinca, Phikolomzi	RSA	SU	B	M	Continuing	Independent
Mbobo, Tumeka S.	RSA	SU	B	F	Continuing	Independent
Mbonani, Sipho	RSA	Wits	B	M	Continuing	Full
Mudau, Phuluso	RSA	Wits	B	M	Continuing	Full
Nelufule, Takalani	RSA	UP	B	M	Continuing	Independent
Ngwenya, Duduzile	Zimbabwe	SU	B	F	Continuing	Full
Ntsonge, Sinazo	RSA	RU	B	F	Continuing	Full
Nxele, Beka	RSA	SU	B	M	Continuing	Independent
Ramahlo, M.	RSA	UP	B	F	Continuing	Full
Saccaggi, Davina	RSA	SU	W	F	Completed	Partial
Schoeman, A.L.	RSA	NWU	W	F	Completed	Full
Shivambu, T.C.	RSA	UKZN	B	M	Completed	Partial
Szewczuk, A.M.	RSA	Wits	W	F	Continuing	Independent
van der Colff, D	RSA	SU	C	F	Continuing	Independent
Vorster-Martin, N.	RSA	SU	W	F	Completed	Full
Yapi, Thozamile	RSA	RU	B	M	Completing	Partial