C·I·B

DSI-NRF Centre of Excellence for Invasion Biology

DSI-NRF Centre of Excellence for Invasion Biology

Annual Report

2019

2014 TO 2019 ACHIEVEMENTS IN LINE WITH SERVICE LEVEL AGREEMENT FOR STAGE 6

C·I·B
DSI-NRF Centre of Excellence for Invasion Biology

329 students trained

- 65% women students
- 55% black students
- 11 social science students

36 post-doctoral fellows

72 co-supervised students

947 peer-reviewed papers

12 conferences & workshops hosted

13 visiting fellows from 10 countries

Outreach activities in 16 rural and 7 urban limbovane schools (total: 23)

123 reviews performed for the NRF

Collaborated on:

- **DEFF's National Status Report on Biological Invasions**
- **IUCN's EICAT impact classifications**
- **International Panel on Biodiversity and Ecosystem Services (IPBES)**

Centre for Invasion Biology · Stellenbosch University · www.sun.ac.za/cib · Facebook: CentreForInvasionBiology · Twitter: @InvasionScience

Executive summary

Reporting period	:	1 January 2019 - 31 December 2019
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
Host institution	:	Stellenbosch University

Progress against Key Performance Areas

Research

2019 was another productive year. One hundred and ninety peer-reviewed papers appeared during the year, almost a quarter of them in journals with an Impact Factor of 4 or more; 5 papers appeared in journals with an Impact Factor of over 15. More importantly, C·I·B publications are addressing all the key issues identified as priority areas in our strategic plan. Our research is being used in management and planning and the C·I·B address continues to appear on C·I·B highly cited publications that are contributing to advances in many aspects of invasion science globally.

Education and Training

The C·I·B supported 63 students and 14 post-docs during 2019. Our students continue to be in demand for positions in academic institutions and partner organizations.

Networking

A highlight for 2019 regarding international networking was the formal launching of the Global Urban Invasions Biological Invasions Consortium at a workshop in Toronto, Canada, in June. The C·I·B was well represented at the workshop by core team members, associates, students and alumni, and will play an important role in the Consortium. Important benefits are likely to emerge for our partner organizations. Former C·I·B PhD student Luke Potgieter is coordinating GUBIC activities as part of his post-doc at the University of Toronto. The C·I·B's fellowship programme had another successful year, with productive visits from several senior international scientists who participated in many C·I·B activities and linked with many C·I·B partners.

Information Brokerage

Several successful workshops and symposia were convened in 2019. The C·I·B partnered with SANBI to arrange the 2019 National Symposium on Biological Invasions in May. This event is the primary forum for the dissemination of research results on all aspects of invasion science in South Africa and was well attended by researchers and managers from all organizations involved in research and management of invasive species in the country. Workshops were convened on risk analysis, frameworks in invasion science, and restoration ecology. A successful "Study Abroad: field course was held.

Service Provision

The C·I·B continues to make major contributions to the National Status Report on Biological Invasions.

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

15 out of 18 graduates in 2019 were female, showing the impact on production of female South African scientists (73% of the graduates were South African). In terms of the impact of our research, invasions, particularly plant invasions in rural areas disproportionately affect women as they are frequently heads of households. Research from the Centre that is taken up by municipalities and the national government programmes to remove invasive plant species (e.g. Working for Water, Working on Fire and Land Care) benefits clearing programmes in rural areas and on farms. Unfortunately, the take-up of research findings is not uniform, and we are always working on better ways to ensure that government takes up our research findings and improve its practices and policy.

Red Flags

Notification was received late in 2019 that funding from the Department of Science and Innovation would be provided to sustain activities of the C·I·B for the period 2020-2022, at the level of funding for 2019. This provides us with a breathing space after a year of uncertainty on whether the C·I·B would continue operations after March 2020. Our plan is continued operations as "business (almost) as usual" for the next three years. However, special efforts will be made, starting early in 2020, to retool the C·I·B's *modus operandi* to make the centre must less reliant on funding from government. This will inevitably mean diverting some attention away from our core business, but every effort will be made to meet the targets in all our Key Performance Areas.

Another disruption to our operations is likely to come from the implementation of the NRF's proposed new system for allocating and managing bursaries. Several representations were made to NRF to question the need for such changes and to warn them of potential implications. We foresee major disruptions to the smooth functioning of the Centre as a result of these changes.

General Comments

Thanks are due to all people involved with the C·I·B – the hub staff, core team members, associates, students and post-docs, our Steering Committee, the NRF and DSI, and all key contacts at our partner organizations. 2019 was a challenging and stressful year but C·I·B has again "delivered the goods", as shown in the pages of this annual report.

Contents

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. We also explore how interactions among global change drivers, especially climate change and biological invasions, may further influence the impacts of biological invasions.

Our projects and integrated programmes of research target all aspects of the phenomenon of biological invasions, and addresses 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 so the C·I·B undertakes work under these 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.

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. Molecular methods as a tool in invasion science are a cross-cutting theme, as they are becoming increasingly widely used to identify the provenance of introduced species and for uncovering many aspects of the invasion process. The ability to distinguish apparently similar species at the cellular level is a fundamental component of the C·I·B's research toolbox and contributes substantially to many of the research projects detailed below. Further details of many research projects are available on the C·I·B's web site (www.sun.ac.za/cib/). The projects summarized below provide a precis of the wide range of disciplines, taxa, spatial and temporal scales, and scientific approaches in the C·I·B's research during 2019.

Research in 2019 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 is addressing fundamental issues related to the biology of invasive species, aspects of invaded ecosystems, invasion processes, and many facets of the human dimensions of invasions.

1.3 Long-term collaborative research - Long-term change in arthropod assemblages

The C·I·B manages three long-term monitoring transects which gather data on invertebrate communities in relation to altitude, aspect, climate, vegetation and other biological variables. The system is summarised in Table 1. The plan is to analyse long-term data from the three transects separately and together to advance our understanding of the relationship between biodiversity and climate using hyper-diverse insect groups such as ants. The analysis and publication of this work is the basis of ongoing collaborations between C·I·B core team members and the Universities of Monash (Australia) and Oxford (UK). Data from the transects are increasingly being used in global analyses such as the one discussed below.

Table 1. Summary of the C·I·B's long-term monitoring of insect assemblages.

Dates	Sites	Replicates per site	Traps per replicate	Aspect	Sampling periods	Elevation range (m amsl)	Arthropod groups sampled
Cederberg							
2002-2014	17	4	10	W	Mar, Sep	0-1926	Ants, carabid beetles and spiders*, climate
2015 onwards	17	4	10	W	Mar, Sep	0-1926	Climate only
Sani Pass							
2006 onwards	8	4	10	E	Jan, Sep	900-3000	Ants, climate
Soutpansberg							
2009 onwards	11	4	10	N, S	Jan, Sep	800-1700	Ants, beetles and spiders*, climate

**spider by-catch* is donated to the South African National Survey of Arachnida

1.3.1 Low levels of intraspecific trait variation in a keystone invertebrate group

The trait-based approach to ecology promises to provide a mechanistic understanding of species distributions and ecosystem functioning. Typically, trait analyses focus on average values of species traits and assume that intraspecific variation is small or negligible. Recent work has shown, however, that intraspecific trait variation can often contribute substantially to total trait variation. Although many studies have investigated intraspecific variation in plants, very few have done so for invertebrates.

No research has been done on the level of intraspecific trait variation in ants (Hymenoptera: Formicidae), despite the growing body of literature that has used ant morphological trait data to show that these insects play important roles in many ecosystems and food webs.

Data on ant morphology traits from 23 species collected along the C·I·B's Sani Pass transect were used by C·I·B core team member Mark Robertson, former C·I·B post-doc Tom Bishop and a British collaborator (Gaudard *et al*. 2019; *Oecologia* 190: 725–735). They measured 1145 different individuals and made 6870 trait measurements. They found that intraspecific variation accounted for only 1–4% of total trait variation for each of the four traits analysed. No links between intraspecific variation, phylogeny and elevation were found. On average, six individuals generated robust species means but under-biased sampling scenarios 20 individuals were needed. The low levels of intraspecific morphological variation found suggest that the approach of using mean species traits is valid, in this fauna at least. Such insights are crucial for understanding how our biota will respond to climate change and other facets of global change.

1.4 Biodiversity foundations

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 biological invasions themselves. The examples chosen to discuss in this report focus on understanding the dimensions and determinants of species-area relationships, the role of ungulates as seed dispersers, and ways of assessing how roads impact biodiversity.

1.4.1 How many alien species would we expect to find in an area?

A key question in invasion biology is why some regions have more alien species than others. This is likely to depend on features of the local environment, yet how humans influence the invasion process is likely to matter as well. To help our understanding of the determinants of alien species richness, Richard Duncan from the University of Canberra, Phill Cassey from the University of Adelaide, Alex Pigot from University College London (UCL), and C·I·B Associate Tim Blackburn (UCL), developed a general theoretical model of the process (Duncan *et al*. 2018; *Biological Invasions* 21:2665–2677).

The alien species richness of an area depends on how many species were introduced there (colonization pressure), and how many of those introduced species managed to establish a viable population. Establishment success in turn depends on two broad factors: 1) how many times a species is introduced, and how many individuals are introduced in total (together, these comprise the species' propagule pressure); and 2) the probability that a founding individual leaves a surviving lineage (lineage survival probability). We therefore derived a simple general model of an area's alien species richness in terms of just these three key factors: colonization pressure, propagule pressure and lineage survival probability. This model helps us to understand how changes in these factors can influence the number of alien species that end up in an area.

We started by using our model to calculate how many alien species you would expect to have made their home in a given area, if you introduce 100 individuals (10 separate introductions, each of 10 individuals) of each of 100 species, with each individual having just a 1/200 chance of leaving a surviving lineage. The answer was 39. We then varied each of these values in turn to see what effect each factor had on our predictions of alien species — the graph below shows the results.

What is immediately obvious is how many alien species are introduced is the key factor — you end up with many more alien species in an area if you increase colonisation pressure, relative to increasing either propagule pressure or lineage survival probability (Figure 1). This is because alien species richness ultimately must be limited by how many species get introduced. Overall, therefore, the model shows that what people do (in terms of introducing more or fewer species) is the key driver of alien species richness.

"The results of the model make perfect sense", says Tim Blackburn. *"Whatever else varies, how many alien species you get in area is basically limited by how many you introduce. It's then obvious that the best way to avoid ending up with lots of alien species anywhere is not to introduce many."*

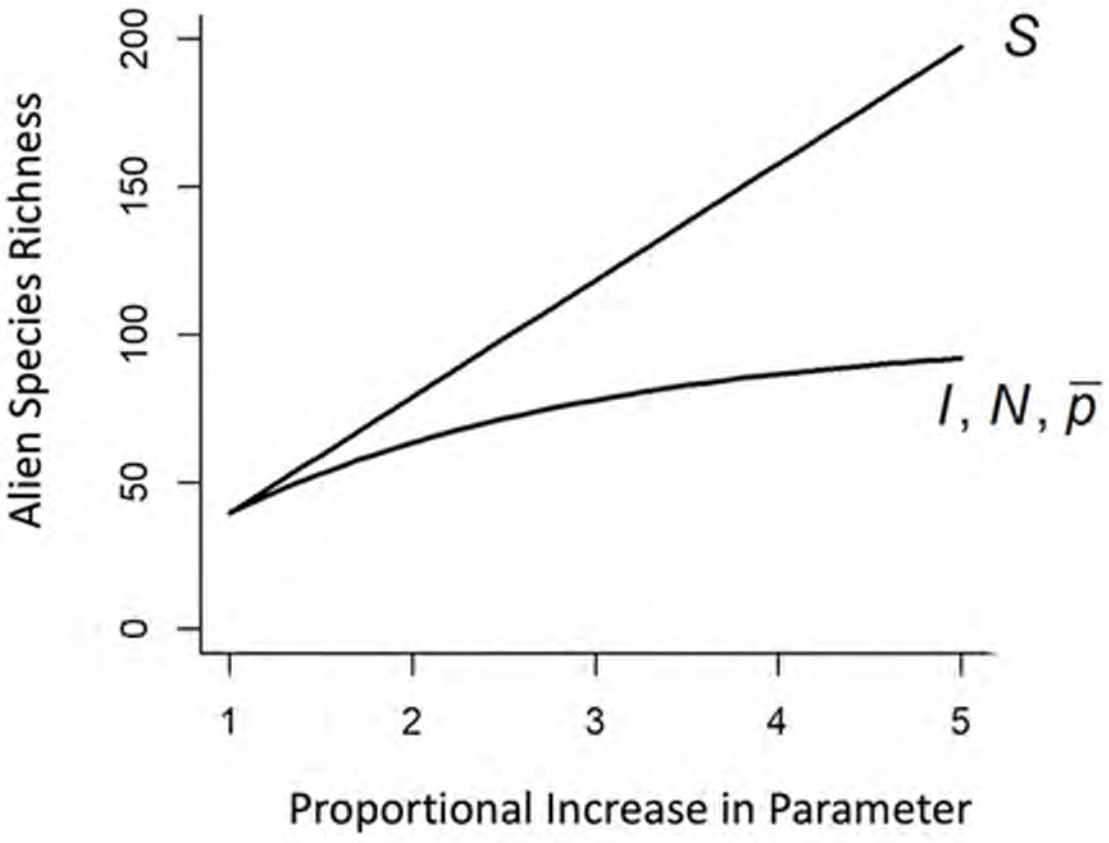


Figure 1. Analysis to show how alien species richness changes with proportional increases in colonization pressure (S), propagule pressure (I and N), and lineage survival probability (p). We specified initial values of number of species introduced to a location S = 100, the number of introduction events per species I = 10, the number of individuals introduced per event N = 10, and lineage survival probability p = 0.005. The model predicts that 39 alien species richness will be present in the area. We then measured the effect on alien species richness of increasing each

parameter (S, I, N and p), in turn, by up to 5 times the initial value, while keeping the other parameters fixed at their initial values. (From Duncan *et al*. 2019)

1.4.2 Ungulates as mediators of long-distance plant dispersal by endo- and epizoochory

There are 257 species of ungulates (animals with hooves) worldwide (Figure 2). These generally large-bodied mammals move diaspores (any part of a plant that plays a role in plant dispersal e.g. spores, seeds, fruits) of nearly half of the plant species available within their home range. Christophe Baltzinger (National Research Institute of Science and Technology for Environment and Agriculture, France) used a C·I·B Research Fellowship in July and August 2018 to develop research initiatives in southern Africa, where communities of ungulates are taxonomically and functionally diverse. He interacted with several C·I·B researchers including core team members Colleen Downs, Cang Hui, Llewellyn Foxcroft and Thabiso Mokotjomela. Together with PhD students, Ushma Shukla (Irstea, France) and Sorour Karimi (Isfahan University, Iran), he published review paper that drew on insights gained in South Africa (Baltzinger *et al*. 2019; *Frontiers in Ecology and Evolution* https://doi.org/10.3389/fevo.2019.00038).

Recent studies have highlighted under-studied ungulate-mediated plant dispersal mechanisms and Christophe and his team took this opportunity to review the different plant dispersal mechanisms involving ungulates, and their implications for the fate of the dispersed diaspores. The team ran a systematic literature review to assess the complementarity and overlap of co-occurring ungulates first for seeds that are dispersed via ingestion (endozoochory) and then for seeds that are moved around on the outside of animals (fur-epizoochory), by looking at the diversity of plants dispersed.

"Our results enable us to provide preliminary recommendations concerning ungulates as potential tools (i.e. rewilding concept) for habitat restoration, thanks to their dispersal services. Associating a Grass and Roughage Eater (e.g. sheep or bison), efficient for quantitative dispersal, with a Concentrate Selector (e.g. moose or roe deer) for qualitative dispersal would create a beneficial complementarity in the restoration program," says Baltzinger. He adds, *"Large ungulates interact with diverse compartments of the ecosystems. We should thus consider them as dynamic actors of ecosystem functioning and realistic options for the management and rehabilitation of degraded habitats."*

Figure 2. Roe deer (*Capreolus capreolus*) is a common ungulate of European lowland ecosystems. Moving and feeding within grasslands favours the attachment of diaspores arranged vertically all along the plant stem (e.g. brown infructescence of Sticklewort, *Agrimonia eupatoria*) in animal's fur. (Photo: Frédéric Archaux)

1.4.3 Much more than just collisions: roads have major impacts in arid environments

The impact of roads extends way beyond their physical boundaries with important implications for ecology and evolution of the surrounding biota. These effects also vary substantially along aridity gradients.

C·I·B Core Team Member Stefan Foord worked with Drs Richard Dean (DSI-NRF Centre of Excellence: Percy FitzPatrick Institute of African Ornithology), Colleen Seymour (South African National Biodiversity Institute) and Grant Joseph (University of Venda) to review the literature on wildlife responses to roads at the arid end of the spectrum (Dean *et al*. 2019; *Diversity* 11:81; doi:10.3390/d11050081).

Drylands are predicted to cover 50% of the earth's land surface by 2100, and while human infrastructure will certainly penetrate even further and faster into these remote areas, only 20% of studies covered in the literature explore the impacts of roads on wildlife in arid regions (Figure 3). From evolutionary changes in the frequency at which grasshopper males call through to road-side bird communities dominated by scavengers with resultant competition effects, roads in arid regions have interesting but mostly negative impacts on biota. Effects mediated by characteristics associated with arid landscapes include sparse vegetation, boom and bust cycles, increased productivity of road verges relative to the surrounding landscape, and the increased reach of light and noise pollution.

The search is on for factors associated with roadkill hotspots and the development of roadside detection systems which often do not have to be high-tech or expensive. Key areas for future research would include the importance of roadkill in local food webs, the impact of the removal of individuals by roadkill on the structure of the local animal communities and services such as pollination.

"The impacts of roads in arid regions differ quite markedly from those in more temperate areas" says senior author of the paper Dr Richard Dean. *"Research on this aspect in South Africa's arid areas to determine impacts of road kills on local food webs is urgently needed"*

Figure 3. The impacts of road kills on local food webs in South Africa's arid areas have received little attention up to now (Photo: Richard Dean)

1.5 Model systems for understanding invasions and their impacts

Several key groups of organisms and settings (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 2019, substantial work was undertaken on many aspects of acacias, ladybirds and *Xenopus laevis*. Some aspects of this work are summarized below.

1.5.1 Acacias as model systems for understanding invasions and impacts

Invasive acacias (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 acacias in South Africa and other parts of the world has created a valuable natural experiment for elucidating many key aspects of invasions science. Australian acacias 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 2019.

1.5.2 Despite state-of-the-art methodology, the introduction history of silver wattle remains poorly understood

C·I·B post-doctoral fellow Heidi Hirsch, working with C·I·B Core Team Members David Richardson and Jaco Le Roux and C·I·B PhD student Maria Castillo, explored the very complex introduction history of the invasive tree Silver wattle (*Acacia dealbata*) in South Africa.

Knowledge of the introduction history (i.e. source(s), number and size of introduction events) of an invasive species is crucial for understanding its invasion success and to facilitate effective and sustainable management approaches. Silver wattle, native to eastern and south-eastern parts of mainland Australia and Tasmania, is a widespread and globally important invasive tree. In South Africa, where it was introduced in the mid-19th century, the species invades riparian habitats in the north-eastern summer-rainfall regions where it displaces and changes native vegetation. Tracing the invasion history of Silver wattle in South Africa based only on historical records is impossible, however, because silver wattle were commercially distributed for a range of purposes, often without documentation on the origin of the seed material.

Hirsh *et al*. used a combination of genetic fingerprinting and state-of-the-art genetic modelling to compare the genetic make-up of populations sampled across the native range of the species and in its non-native range in South Africa. They also sought to determine the most likely introduction scenario using a method called Approximate Bayesian Computation Analyses which quantify the level of support that data lend to particular values of parameters and to choices among different models (Hirsch *et al*. 2019; *American Journal of Botany* 106: 352-362).

Surprisingly, even with a very comprehensive sampling of native and alien ranges, and using sophisticated analytical methods, it was not possible to identify from where, or how many times, Silver wattle had been introduced to South Africa. Instead, the analyses revealed a clear genetic distinctiveness, and lower genetic diversity and structure in invasive populations compared to native populations. The most likely introduction scenario involves an unknown source population. Further work is being conducted to examine genetic patterns in worldwide populations to shed more light on global movements of the species.

"Our results imply that invasive populations of Silver wattle in South Africa have a very complex introduction history, possibly linked to evolutionary change and introduction from populations in the invasive range, rather than the native range" says Heidi Hirsch. *"The next step is for us to investigate invasive populations from other parts of the global invasive range of the species. This will help us, not only to gain a more comprehensive understanding on the species' global invasion history, but also, hopefully, to find the missing historical link regarding its introduction to South Africa."*

RIPARIAN WATER AVAILABILITY AFFECTS POTENTIAL NITROGEN POLLUTION BY BLACK WATTLE

The leaf nitrogen dynamics of the widespread invader Black wattle (*Acacia mearnsii; Figure 4*) under conditions of varying water availability in fynbos riparian zones have not yet been examined. C·I·B PhD student Casparus Crous, C·I·B Core Member Karen Esler and colleagues studied nitrogen dynamics across fynbos riparian zones in the Western Cape.

Non-legumes rely mainly on soil-available ammonium and nitrate, whereas legumes such as Black wattle are capable of fixing atmospheric nitrogen via microbial action, thereby adding nitrogen to the soil. By having this ability, legumes are expected to accumulate higher levels of nitrogen in their plant material (e.g. leaves, seeds, stalks) compared to non-nitrogen-fixers.

By comparing the nitrogen content of Black wattle leaves to that of two native, co-occurring, and non-leguminous tree species, Wild Almond (*Brabejum stellatifolium*) and Cape Lance-leaf (*Metrosideros angustifolia*), Crous and colleagues found that the invasive legume was functionally different from both of the native species. The invasive species had far more leaf nitrogen.

Another factor that influences the nitrogen dynamics in landscapes is water availability. Indeed, the authors found that more water-stressed plants had lower leaf nitrogen, meaning lower riparian water availability limited the nitrogen source and uptake by Black wattle, and vice versa.

"This finding shows that patch-scale water availability, or site hydrology, is important to Black wattle form and function, potentially affecting nitrogen pollution estimates locally and downstream," said Casparus Crous. *"From a practical standpoint, dense Black wattle stands in wetter riparian zones are predicted to deposit more nitrogen into the soil and stream and should be prioritised for clearing if lowering nitrogen pollution in freshwater ecosystems was the most critical goal."*

Figure 4. Black wattle, *Acacia mearnsii*. (Photo: Suzaan Kritzinger-Klopper)

1.5.3 Alien acacias as drivers of secondary invasions

Unfortunately, clearing stands of the invasive alien tree Port Jackson (*Acacia saligna*) do not always trigger the recovery of native plant communities because secondary invaders may be dominant and persist up to three years after clearing at levels similar to, or higher than the first year after clearing (Figure 5). This was the finding of a recent study conducted in the South African fynbos by a group of C·I·B researchers led by former C·I·B PhD student (and currently post-doctoral fellow at the C·I·B) Dr Mlungele Nsikani.

Approximately 70 species of Australian acacias have been introduced to South Africa and at least 14 of these are currently invasive, with Port Jackson being one of the most widely distributed species.

The fynbos biome is the greatest casualty of *Acacia* invasions as they have negative impacts on native plant diversity, ecosystem function and services.

It is often assumed that manually clearing invasive species will lead to the reduction of their negative impacts and the recovery of native plant species. The "fell, stack and burn" method, i.e. fell the invasive species, stack the slash and allow it to dry before burning it, has been widely applied to reduce the cover of invasive acacias. However, instead of facilitating the recovery of native plant species, clearing of target invasive species can lead to an increase in the abundance of non-target alien species (secondary invasions).

Data collected for the study showed that up to 32 species could be secondary invaders after the clearing of Port Jackson. This secondary invasion was mainly favoured by the burning of the stacked slash (e.g. wood, leaves, branches and twigs). Fire application after clearing invasive acacias can favour the growth of non-target invasive species. It can also have a positive effect by triggering mass germination of *Acacia* seeds through low-intensity fires.

Nsikani's research suggests that slash should be spread throughout the restoration site rather than stacked and burnt. *Acacia* seedlings that germinate can be then be manually weeded, mowed or treated with herbicides. Management of secondary invaders can take place afterwards.

"*Dealing effectively with secondary invasions is the new frontier in the quest for sustainable management of invasive plant species in systems like our fynbos*" says Dr Mlungele Nsikani. "*We need to start paying much more attention to this issues so that we can adapt our management techniques if we are to have any hope of achieving effective restoration of ecosystems degraded by wattles in South Africa*".

Figure 5. Measuring the species richness and cover of secondary invaders in the field. (Photo: Mashudu Mashau)

1.5.4 Xenopus laevis - a globally significant invasive amphibian

The African clawed frog, *Xenopus laevis*, is one of the world's most widely distributed amphibians. Exported from the Western Cape for pregnancy testing in the 1930s, it has become a standard

laboratory amphibian, and a model species for studies in many biomedical fields. However, this success has been commensurate with introductions into novel environments, both deliberate and accidental, such that the species is now invasive on four continents. Interest in researching the impacts of this invasive species has spiked recently, and scientists in all the invaded countries are forming a multi-disciplinary team which will tackle autecology, demographics, physiology, performance, genetics , combining these into species distribution models. During 2019, the C·I·B contributed to research to the expanding knowledge of the global range of this amphibian.

1.5.5 Xenopus adds another continent to its global range

A new population of African clawed frogs (*Xenopus laevis*) has established in mainland China. C·I·B Core Team Member John Measey, working with colleagues from the Chinese Academy of Sciences, trapped frogs at a site near the city of Kunming, Yunnan Province, China (Figure 6) (Wang *et al*. 2019; *BioInvasions Records* 8:457–464). The African clawed frogs they found were all albinos, the most common form in the pet trade. Previous work by Measey had shown that the vast majority of African clawed frogs moving around the world in the pet trade originate from China.

Invasive populations of African clawed frogs are known in Europe, North and South America and were previously only known in Japan in Asia. This discovery now places an invasive population on continental Asia with the potential for a much larger invasion in this area. These frogs are known to have major impacts on local amphibian and invertebrate populations.

Figure 6. Traps out in the evening at the side of the aquaculture area. These simple bucket traps are baited with chicken livers to attract the African clawed frogs. (Photo: John Measey)

Trade in the African clawed frog started in the 1930s following their use as the first pregnancy test. The species was so easy to keep that it then became the standard laboratory amphibian all over the world, a status it continues to enjoy today. Breeding in laboratories has become so successful that animals are no longer exported from South Africa. Since the 1980s, however, this species has become very popular in the pet trade. Now hundreds of thousands of animals are shipped around the globe destined to become aquarium pets.

The researchers used molecular methods to check whether members of the invasive population carried the fungal chytrid pathogen, known for decimating amphibian populations globally. All frogs caught tested negative. However, the site is known for having a population of American bull frogs, which the team heard calling as they set out the traps. It is unknown how these two globally invasive frogs interact.

"The site is on the edge of Lake Kunming, possibly allowing these frogs access to a large area in southern China", said Prof. John Measey. *"We were surprised to find an established population as this area fell outside the area identified as being suitable for the species in bioclimatic models."*

1.5.6 Ladybirds as a model group

Some of the worst invasive species worldwide are insects. These species provide an excellent system to explore traits associated with invasiveness and how this information can be used to reduce impacts on native species and ecosystems. In contrast to plants, most insect introductions are unintentional, thus minimizing bias in pre-introduction trait selection (except for bio-control species) and they have fast generation times thereby providing the possibility to explore adaptation and competition with native species. Insects are easily maintained in the laboratory and can be exposed to a variety of biotic and abiotic conditions with relatively little workspace required and evolutionary fitness consequences can be measured directly in experimental trials. Work on several species of ladybirds has already been conducted at the C·I·B and has shown that this group is an excellent model system to further knowledge of insect invasions. Work published in 2019 dealt with the evolution of physiological performance of alien ladybirds in the face of climate change.

THE EVOLUTIONARY POTENTIAL OF AN INSECT INVADER UNDER CLIMATE CHANGE

Although the impacts of climate change and invasive species are typically studied in isolation, they interact to reduce the viability of plant and animal populations. Indeed, invasive species, by definition, have succeeded in areas outside of their native range and may therefore have higher adaptive capacity relative to native species. Nevertheless, the genetic architecture of the thermal niche, which sets a limit to the potential for populations to evolve rapidly under climate change, has never been measured in an invasive species in its introduced range.

C·I·B post-doc Mike Logan, working with C·I·B core team member Susana Clusella-Trullas and C·I·B PhD student Ingrid Minnaar, estimated the genetic architecture of thermal performance in the Harlequin ladybird *Harmonia axyridis* (Logan *et al*. 2019*; Evolution* https://doi.org/10.1111/evo.13885.). They collected hundreds of individuals around Stellenbosch, where this invasive species has established and spread since the early 2000s. The authors measured thermal performance curves for walking speed in more than 400 third-generation offspring reared in the laboratory from a paternal half-sib breeding experiment and analysed the genetic variance–covariance matrix. Results showed that while the critical thermal limits, the maximum and minimum temperatures, tolerated in this species have an additive genetic basis and are heritable, most other

components of the thermal performance curve have low heritability. For example, the centre of the curve or the temperature at which the beetles perform optimally is not heritable. They also found evidence that genetic correlations may constrain the evolution of this beetle performance under climate change.

Susana Clusella-Trullas says "some invasive species may have limited evolutionary capacity under climate change, despite their initial success in colonizing novel environments". "Results of this research showed that if climate warming entails an increase in optimal temperature, the harlequin beetle has little evolutionary potential to shift its thermal optimum while more adaptive capacity may take place if climate change results in frequent temperature extremes. However, trade-offs and correlations among traits need to be considered as these impose additional evolutionary bounds. More generally, this study shows that the ability of invasive species to establish and thrive beyond the native range does not provide a good indication of their ability to adapt to climate change. Both genetic and plastic facets of climate change adaptation need to be considered when predicting invasive species distributions and responses to climate change.

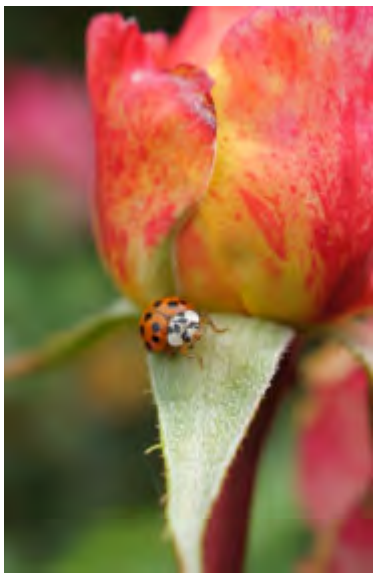


Figure 7. *Harmonia axyridis* has spread rapidly across South Africa, including cold and warm parts of the country. Understanding their thermal biology and response to climatic changes will improve our predictions on its persistence and on its impact on native ladybird species ((Photo: Ingrid Minnaar)

1.6 Detection, demonstration, responses and remediation

FIRST SCREENING OF ENTOMOPATHOGENIC NEMATODES AND FUNGUS AS BIOCONTROL AGENTS AGAINST THE SUGARCANE LONGHORNED BEETLE

The screening of several biocontrol agents revealed that the larvae of an emerging pest, a sugarcane longhorned beetle, show high resistance to both an entomopathogenic fungus (EPF) and nematodes (EPN). This conclusion is based on experiments aiming at testing the virulence of different locally isolated EPN and EPF species, but also at helping understand the resistance methods of this pest. The research was conducted by C·I·B post-doctoral fellow Dr Marion Javal, C·I·B Core Team Member John Terblanche, and colleagues, all at Stellenbosch University's Department of Conservation Ecology and Entomology.

The sugarcane longhorned beetle (*Cacosceles newmannii*) is a cerambycid native to Mozambique, eSwatini and South Africa. The biology of this beetle is poorly known, and its host plants have not yet been fully determined. In 2015, larvae of this beetle were feeding on commercially grown sugarcane in KwaZulu-Natal. They dig galleries into the sugarcane stool and upwards into the stalks, but are mainly found in the underground stalks. The reasons underlying the shift of this longhorned beetle from its primary host plants to sugarcane remain unclear. However, this species has the potential to spread and cause considerable agricultural and economic losses.

This study was the first to assess the effectiveness of several EPNs and one EPF as biocontrol agents against of the longhorned beetle. Overall, larvae of the sugarcane longhorned beetle appeared to be resistant to the biocontrol agents. Only one of the EPNs species, *Steinernema jeffreyense*, caused larval infection, at very low levels. One reason for this is that the symbiotic bacteria associated with the nematodes, which cause death of the beetle larvae by septicaemia, failed to develop in the larvae's body, leading to a very slow development of the nematodes (Figure 8).

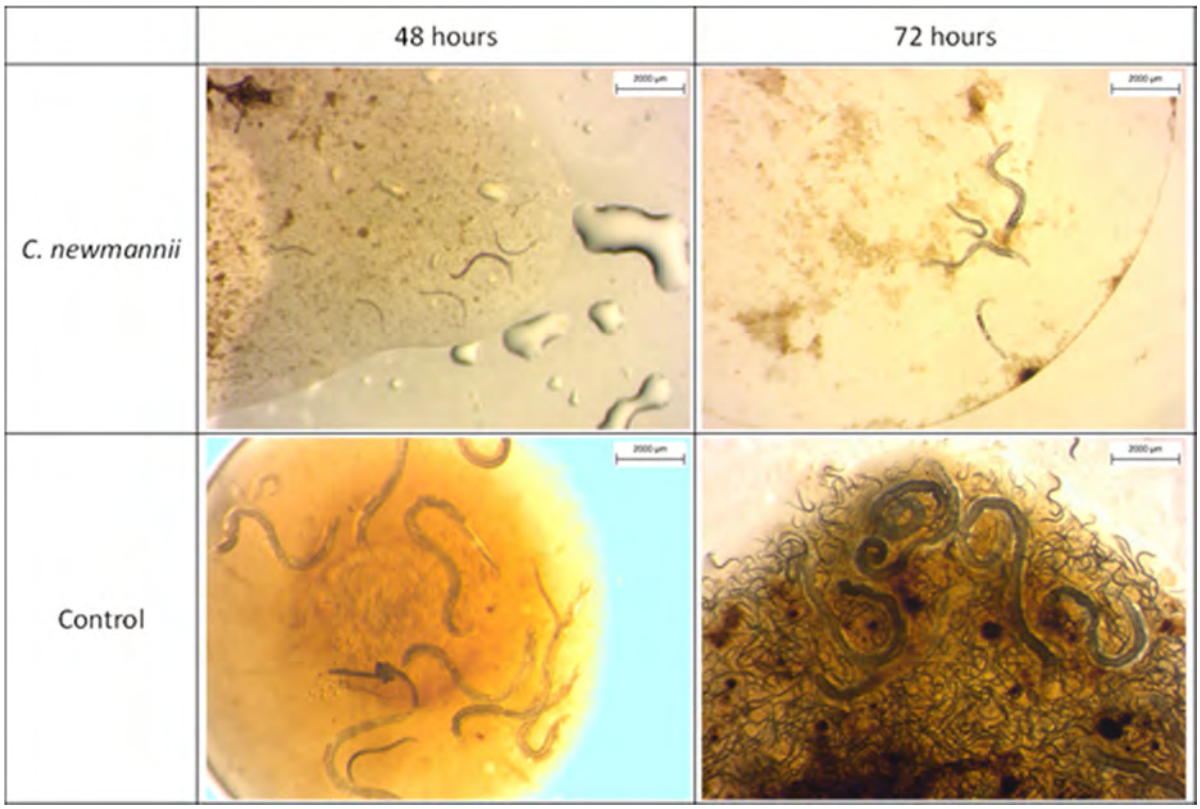


Figure 8. Illustration of *Steinernema jeffreyense* development in sugarcane longhorn beetle (*C. newmannii*) haemolymph (top line), and in greater wax moth (*Galleria mellonella*), known to be highly susceptible to nematodes infection haemolymph, after 48 and 72 hours. (Photo: Marion Javal)

Integrated pest management (IPM) is an approach that aims at reducing pest populations, while limiting pesticide use and therefore increasing environmental and human health. *"IPM often implies the use of complementary methods that can work synergistically"* says Marion Javal. She adds, *"The*

biocontrol agents we used in this study showed limited success in increasing larval mortality, but their pathogenicity needs to be investigated when coupled with other biopesticides or natural enemies".

WHERE DID INVASIVE GUTTURAL TOADS COME FROM?

Guttural toads (*Sclerophrys gutturalis*) have been invasive in Mauritius and Reunion for nearly 100 years (since ~1922). These toads have been in Constantia (near Cape Town) for 20 years, but nobody knew where they came from. This was the central question behind the MSc study of Nick Telford (now of SANBI, but then of University of the Western Cape) in which C·I·B core team member John Measey participated.

The Guttural Toad, *Sclerophrys gutturalis*, has a large distribution in Africa, from Ethiopia in the North to South Africa in the South, and from Angola in the West to Mozambique in the East. That is one of the largest distributions of any of Africa toad.

Nick took tissues of toads that had been collected from all over the continent, plus those sequences already publicly available (on GenBank), and to them he added his own collections around South Africa. Tissues were also obtained from invasive populations in Constantia, Mauritius and Reunion. He sequenced a common mitochondrial gene and made a phylogeny with all the sequences. The result was somewhat surprising: all the invasive populations shared alleles that were naturally found around the South African port city of Durban (Figure 9). This means that all invasions likely came from the same area.

The result fits in well with the historical information already published on Guttural Toad invasions. Gabriel Regnard, a Director of the dock management company in Mauritius, was known to have introduced them to Port Louis. It seems most likely that Regnard had sourced the animals from a nearby port. From Mauritius they were introduced to Reunion in 1927. Guttural Toads were first heard calling from the garden of Jonathan Ackerman, soon after the family relocated from Durban in 2000. The genetics suggests that the animals they moved may have been eggs or tadpoles, which they could have moved unwittingly with ornamental pond plants.

Knowing that all toads originated from Durban, has made it easier to study these invasions together, as we have been able to compare both invasive populations and those of the source in one study. With the publication of this genetic study researchers can continue to explore invasions of the Guttural Toad. There are also some oddities in the genetics which suggest some more investigation, like the most southerly records of animals from Port St Johns and Coffee Bay, which appear to have the genetic signature of animals from Gauteng.

"Finding the origin of these invasions is important in such as wide-ranging species," said John Measey of the C·I·B, *"as it will give us a population with which we can compare the invasive populations. Using this we can discern how the invasions have succeeded and predict where else this species may become problematic."*

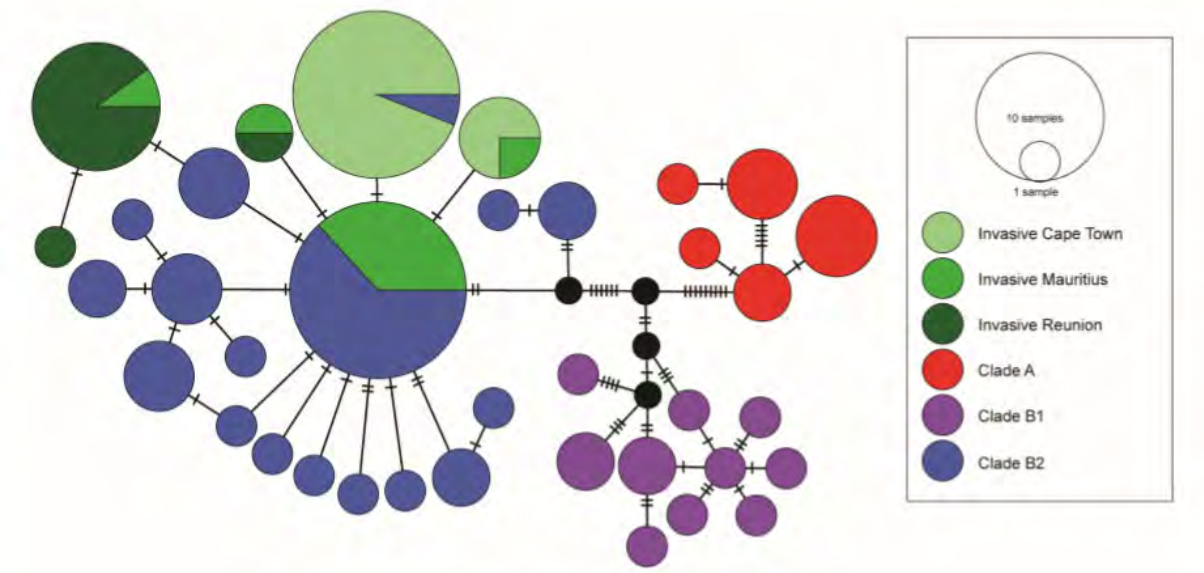


Figure 9. TCS haplotype network of the Guttural Toad (*Sclerophrys gutturalis*). Dashes on the network indicate single mutational steps and black circles represent inferred missing haplotypes. Haplotypes are coloured according to the phylogeny and the number of samples in each haplotype is indicated by the size of the circle

THE SILENT AND HIDDEN MOVEMENT OF LATENT PATHOGENS AROUND THE WORLD

A recent study by Fahimeh Jami from the Forestry and Agricultural Biotechnology Institute (FABI) at the University of Pretoria, together with C·I·B core team members Jaco Le Roux and Dave Richardson, examined the geographical and host range of *Botryosphaeriaceae*, a family of fungi that are common pathogens on woody plants. This study provided the first *Botryosphaeriaceae* records for both the locations and hosts studied.

Endophytes are groups of fungi that live inside their hosts without causing any harm, however, some are latent pathogens that can cause severe damage when their hosts are under stressful conditions. The stresses include drought, hail, insect damage or moving to a new habitat. The *Botryosphaeriaceae* family is one of the most cosmopolitan latent pathogens occurring on woody plants.

The highland tamarind (*Acacia heterophylla*) and Koa (*Acacia koa*) are indigenous to La Réunion and Hawaiian Islands, respectively. These trees are most closely related to each other, but they occur over 16,000 km from each other, on their respective islands. The authors identified 10 *Botryosphaeriaceae* species from asymptomatic branches of *A. koa* and *A. heterophylla*. Four unique species were identified from *A. koa* and five species from *A. heterophylla*. Only one species, *Neofusicoccum parvum* that has a global distribution and wide host range, occurred in association with trees from both islands (Figure 10). Their results expand the geographical and host range of fungal family *Botryosphaeriaceae*, and provide the first *Botryosphaeriaceae* records for both the locations and hosts studied.

The *Botryosphaeriaceae* species are clearly promiscuous and they are not known to be transferred vertically i.e. internally with seed. All evidence suggests that *Botryosphaeriaceae* species have been moved widely by humans through the global trade in plants and plant products. Most of the species detected in this study have been found elsewhere in the world, therefore, anthropogenic movement of plant materials could have brought most of them to these islands. In addition, the wide host range of *Botryosphaeriaceae* species together with their adaptability to a wide climatic range, contribute to their ability to establish and spread in new areas after introduction.

"Quarantine is not always feasible", says Fahimeh Jami, *"this study offers caution to the global trade to decrease invasions, and the asymptomatic plant materials do not mean they are healthy and free of the pathogens"*.

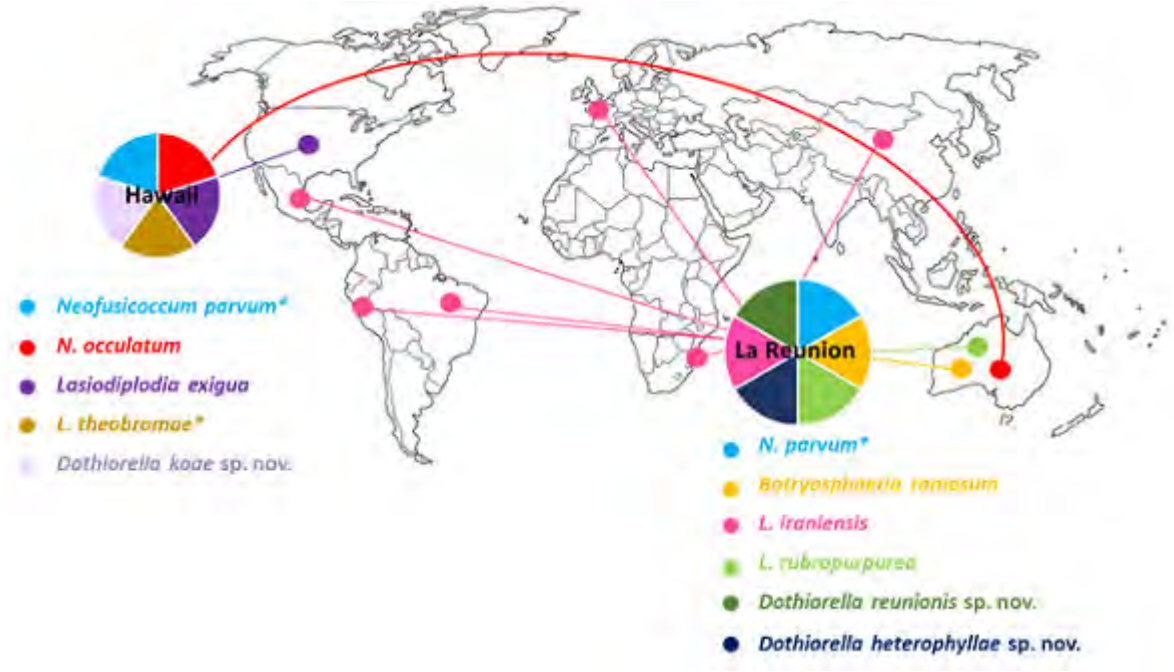


Figure 10. The distribution of ten Botryosphaeriaceae species of this study in Hawaii and La Réunion Islands and across the world. *These two species exist all over the world (Figure from Jami et al. 2019)

REFINING THE DISTRIBUTION OF CO-OCCURRING INVASIVE SPORTFISHES AND THEIR HYBRIDS

Multiple species of black bass (a collective term that refers to members of the genus *Micropterus*, including Largemouth Bass *Micropterus salmoides* and Florida Bass *Micropterus floridanus*) were introduced to southern Africa and form the basis of an important recreational fishery (Figure 11). First introduced in the 1920s, Largemouth Bass are now present throughout South Africa, and Florida Bass were subsequently introduced in the 1980s to promote growth in existing bass populations. Where Florida Bass and Largemouth Bass co-occur, they produce hybrids that are only reliably identified using genetic methods.

Figure 11. John Hargrove holding a Florida Bass (*Micropterus floridanus*). (Photo credit: Drew Dutterer)

C·I·B Core team member Olaf Weyl (South African Institute for Aquatic Biodiversity) together with John Hargrove and Jim Austin (University of Florida), and Honggang Zhao and Eric Peatman (Auburn University), used cutting-edge molecular tools to refine and characterize the spread of Florida Bass alleles among Largemouth Bass populations in southern Africa. Thirteen populations were sampled; these represented popular angling destinations in Mozambique, Botswana, Tanzania, and South Africa. Using 38 species-diagnostic single nucleotide polymorphisms (SNPs), they quantified levels of genetic introgression and the frequency of different hybrid classes among populations.
This study identified select populations initiated with Largemouth Bass that have become dominated by Florida Bass alleles suggesting the potential selective advantage of Florida Bass in specific environments. The work also identified Florida Bass alleles in a population that was characterized as pure Largemouth Bass based on earlier DNA analysis.

"Combined, these findings suggest Florida Bass alleles are more widespread in southern Africa than previously recognized and that new DNA technologies afford greater resolution in individual estimates of hybridization," says John Hargrove.

SAMPLING RECREATIONAL VESSELS FOR MARINE ALIEN FOULING SPECIES

Research by C·I·B post-doctoral associate Koebraa Peters, C·I·B Core Team Member Tammy Robinson-Smythe, and SANBI's Marine Programme Manager Kerry Sink showed that the most effective method for sampling recreational vessels for marine alien fouling species is to combine diver-based and lab-based methods (Peters et al. 2019; *Journal of Environmental Management* 230: 159-167).

Recreational vessels, such as yachts, play an important role in the spread of marine alien species intra-regionally. These species are transferred through biofouling, the growth of organisms onto submerged sections of vessels. Currently, there is no legislation in place to monitor, or manage

marine alien species in biofouling assemblages in South Africa and many regions across the world. This poses a problem since recreational vessels are able to move freely between marinas and often travel to pristine locations. There is currently also no systematic method for monitoring these vessels for alien species.

In order to develop such a system, there was a need for a cost effective yet effective approach to sample vessels. Such a system would be particularly useful in regions where resources are limited for managing marine alien species.

Peters and colleagues applied four sampling approaches to yachts, using both divers and a remotely operated vehicle (ROV). These were used to sample 53 yachts across four marinas in the Western Cape of South Africa. The submerged areas of the yacht hulls and niche areas (i.e. rudder, propeller, keel and water inlets) were inspected for alien species (Figure 12).

In their survey, Peters and colleagues found that collecting scrape samples from hulls, combined with visual inspections by divers was the most effective method for detecting marine alien species. This allowed the researchers to detect as many alien species as possible in scrape samples and to target niches, which are often more susceptible to being fouled.

The researchers also considered the cost of each approach used. Although collecting and processing scrape samples was one of the most expensive methods, it was the most cost-effective approach yielding the lowest cost per species detected. The use of the ROV had low efficacy and incurred high costs.

Not only were the researchers able to identify the most effective method to employ, they also developed a framework for managers to be able to objectively choose an approach that would be most effective to sample yachts for alien species, whilst considering their financial and logistical constraints.

"Studies that consider the economic and logistical implications of monitoring and management approaches are vital for the advancement of marine alien species management, particularly in developing countries" explains Koebraa Peters. She adds that *"our research shows the importance of yachts as carriers of marine alien species in South Africa and has advanced our knowledge regarding the techniques that can be used to sample fouling assemblages for alien species."*

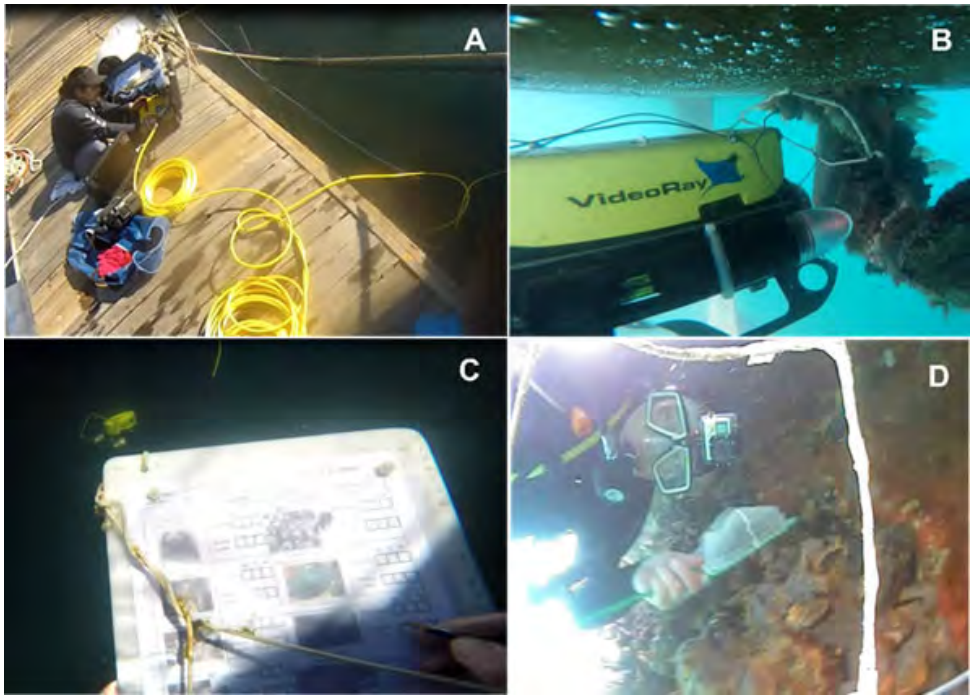


Figure 12. GoPro images: (A) Koebraa Peters controlling the ROV from the surface; (B) ROV collecting a visual sample from a niche area of a yacht; (C) the diver recording alien species detected from diver visual samples and (D) an ROV image of the diver collecting a scrape sample from a yacht hull. (Photo: Koebraa Peters)

1.7 Global environmental change and ecosystem services

THE VULNERABILITY OF LIZARDS TO WARMING

Climate data are increasingly accessible and are being used to predict which species are most vulnerable to climate change. The available datasets often consist of monthly measurements or predictions for locations every dozens or hundreds of kilometres. Can such coarse data provide realistic vulnerability assessments for small organisms? To answer this question C·I·B post-doctoral fellow Raquel Garcia, core team member Susana Clusella-Trullas and former C·I·B student Jessica Allen examined the thermal landscape that lizards experience on the ground (Figure 13).

As ectothermic species, lizards depend on their environment to achieve optimal body temperatures that maximise performance. They can be seen basking in the sun or actively foraging in the morning of a summer day, but they retreat to refuges in rock crevices or under the shade of plants in the peak of the heat. The same shuttling strategy can help lizards buffer the effects of future warming to some extent. Capturing the thermal heterogeneity that exists within a lizard's home range is thus critical in vulnerability assessments, but it requires data at finer scales than those of readily available global datasets.

The new study used a unique fine-scale dataset collected in the Hottentots-Holland Nature Reserve, home to the Girdled Lizard (*Cordylus oelofseni*). The data describe the temperatures available across a small rock outcrop, in 28 micro-sites covering different levels of sun and wind exposure, orientation and substrate, every five minutes for five years. To assess the lizard's vulnerability to

warming, the authors calculated popular indices that compare available habitat temperatures to the species' preferred or critical body temperatures. To test the effect of scale, the authors sub-sampled the dataset in time or in space and recalculated the indices. The results clearly showed that coarser data could lead to inaccurate assessments, with large uncertainty depending on the data subset used.

Scale has been described by Simon Levin as *"the fundamental conceptual problem in ecology, if not in all of science"*. The choice of spatial and temporal scale is a frequent point of debate in assessments of species' vulnerability to warming. The new study shows the implications of choosing inappropriate scales to compute popular vulnerability indices such as Thermal Safety Margin and Habitat Thermal Quality. To be meaningful, indices assessing organismal vulnerability should rely on habitat temperature data that match, as much as possible, the scale at which the organism experiences the environment. *"Accessing fine-scale data is not always feasible"*, says Raquel Garcia, *"but this work offers a word of caution to biologists who use these indices and to conservation practitioners who rely on index estimates"*.

Figure 13. To measure the habitat temperatures available to *Cordylus oelofseni* (left), the study's authors used 'operative temperature models' (right). These models were hollow copper replicas of the lizards, with a temperature sensor inside that was connected to a central data logger. By mimicking the thermal properties of live organisms in the absence of physiological function, these models can accurately predict the temperature that a live organism would experience in the same location. (Photos by Raquel A. Garcia)

ASSESSING IMPACTS OF MEXICAN SUNFLOWERS TO RURAL AFRICAN FARMERS

Mexican sunflowers (*Tithonia* species) are promoted as a green manure, but a survey of rural farmers revealed that these species are invasive and have substantial negative impacts in addition to their benefits. Drs Arne Witt (Centre for Agriculture and Biosciences International, Kenya and C·I·B Research Fellow), Ross Shackleton (Former C·I·B PhD student and post-doc) and Prof. Brian van Wilgen (C·I·B Core Team Member) conducted a distribution survey of *Tithonia* species in 11 African countries from Ethiopia to South Africa (Witt et al. 2019; *Bothalia* 49(1), a2356. https://doi.org/10.4102/abc.v49i1.2356). Household interviews were also held to gauge perceptions of people on *Tithonia diversifolia's* impacts on local livelihoods in Zambia's Copperbelt province.

Three species of *Tithonia* were found to be widespread in Uganda, Kenya, Tanzania, South Africa, Malawi, Zambia, Swaziland, and Zimbabwe (Figure 14). Given the widespread distribution of these species, and the fact that they are invasive, it is important to understand what impacts they may have in order to derive appropriate management responses. The household surveys revealed that farmers in Zambia regarded *Tithonia diversifolia* as having some benefits as a green manure plant, but also that the plants had negative impacts on native vegetation, mobility or access, water availability, crop yields and animal health. Most of the farmers interviewed thought that the costs outweighed the benefits. In particular, costs associated with movement, access and reduced grass cover were regarded as high, with additional negative impacts on water availability, crop yields, livestock health and tree cover.

Figure 14. Mexican sunflowers (*Tithonia diversifolia*) are invasive species that are widely distributed across southern and eastern Africa, where they impact negatively on rural livelihoods and biodiversity. (Photo credit: Greg Forsyth)

The fact that the use and further dissemination of Mexican sunflowers is still promoted despite the considerable negative impacts they have on the livelihoods of rural farmers in Africa, indicates that their net effect has not been adequately considered. The study therefore recommends that detailed cost-benefit studies should be undertaken to support informed decisions on the future management of these species.

"We believe strongly that further promotion of these species by various development agencies should be discouraged," said Brian van Wilgen, *"as the costs of invasions to livelihoods will rapidly outweigh any benefits that accrue from Mexican sunflower use, considering their potential for further spread and densification."*

1.8 Human dimensions

THE IMPORTANCE OF UNDERSTANDING DIFFERENT TYPES OF UNCERTAINTY IN INVASION SCIENCE FOR EFFECTIVE MANAGEMENT

Uncertainty is part of any scientific field. The point of scientific research is to acquire knowledge and to deal with different types of uncertainty to improve our understanding of natural phenomena and help us make projections about the future. Being able to make such projections is particularly important in invasion science as it is necessary to design and implement sound management actions.

Invasion science is a particularly complex field because it straddles many different disciplines, including biological, ecological and social sciences. This complexity makes it particularly subject to uncertainty — and this is problematical for the management of invasive alien species.

As the identification of uncertainties is the first step towards their resolution, C·I·B post-doctoral fellow Guillaume Latombe and colleagues proposed a four-component classification of uncertainties in biological invasions (Latombe et al. 2019; *Ecosphere* Article e02669 doi:10.1002/ecs2.2669). They elaborated on the need to (1) clearly *circumscribe* the phenomenon; (2) measure and provide evidence for the phenomenon (i.e., *confirmation*); (3) understand the mechanisms that *cause* the phenomenon; and (4) understand the mechanisms through which the phenomenon results in *consequences* (Figure 15).

Reflecting the complexity of the field, using multiple examples across different taxa and environments, the authors show that these issues can belong to three major types of uncertainty: linguistic (related to the way we refer to biological invasions), psychological (related to the stakeholders concerned by biological invasions) and epistemic (related to our knowledge on biological invasions). These different types of uncertainties have different effects on the management of invasive alien species and require specific solutions to be resolved.

"While many of the uncertainties cannot be eliminated completely, we believe that using the framework proposed in this paper to explicitly identify and communicate them will facilitate better collaboration between researchers and managers, increase scientific, political, improve public support for invasion research, and provide a stronger foundation for sustainable management strategies," explains Guillaume Latombe, lead author of the study.

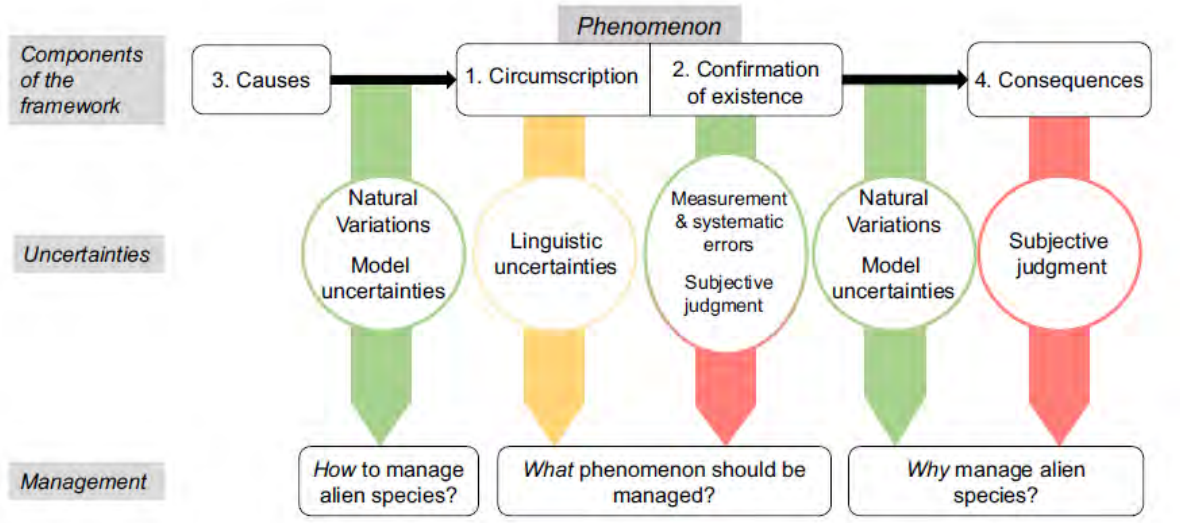


Figure 15. The four-component framework (circumscription of the phenomenon, confirmation of the existence of the phenomenon, mechanistic causes of the phenomenon and mechanistic consequences) upon which sustainable management actions must be built. These components are subject to specific types of uncertainties (linguistic in yellow, psychological in red and epistemic in green) which can hinder the implementation of management actions and policies. The "natural variation" uncertainties concern the mechanisms that result in alien species establishing and spreading, and through which alien species generate an impact, and therefore originate from the arrows. The other uncertainties concern the components themselves and therefore originate directly from them (From Latombe et al. 2019)

INTEGRATIVE RESEARCH FOR INVASIVE ALIEN PLANT MANAGEMENT: CROSSING DISCIPLINARY AND SOCIETAL BOUNDARIES

Biological invasions are a major threat to already complex social-ecological systems and require the integration of knowledge from various disciplines and stakeholders. Accordingly, there have been strong calls for integrated approaches to developing solutions that address the threat.
A study conducted by Brent Abrahams (C·I·B PhD student) and supervised by Karen Esler (C·I·B Core Team Member) and Nadia Sitas (Centre for Complex Systems in Transition, Stellenbosch University), used qualitative content analysis to provide an overview of the research produced under the auspices of the Working for Water Programme (now part of the Natural Resources Management Programme of DEFF) from 1995 to 2015 and to assess the extent to which research outputs reflect the integration of diverse disciplines.

The study found that Working for Water-associated research focused mainly on the ecological processes and impacts associated with invasive alien plants and biological control, while social science and operationally focussed research are under-represented and few and far between (Figure 16). The over-representation of ecological research may be concerning to funders, like Working for Water, because more social and economic studies are needed to inform and guide their decision-making. However, in the context of invasion biology and the management of invasions in the country, the importance and necessity of ecological research should not be ignored. Strong cases

have been made for investing in ecologically focused research and capacity building towards addressing challenges associated with the management of invasive alien plants. While an over-representation of ecologically focused research is not inherently problematic, a lack of integration with economic or socially focused knowledge may be, particularly when addressing social-ecological system challenges.

Integrative approaches to research that engage the social sciences is necessary to solve complex social-ecological challenges. However, such integrative approaches do not occur automatically - even when public funding encourages integration. Integrative research involves more than simply aggregating several disciplines into a single research project. Instead, such research requires the effective coordination and interaction between relevant stakeholders, creating environments that encourage the incorporation of multiple knowledge systems, as well as a more pluralistic approach towards achieving specific social-ecological system initiative mandates. Encouragingly, there have been efforts towards improving the integration (albeit limited with respect to socially focused research) of numerous disciplines, knowledge systems and stakeholders in the planning and research processes, and towards informing operations within the Working for Water context.

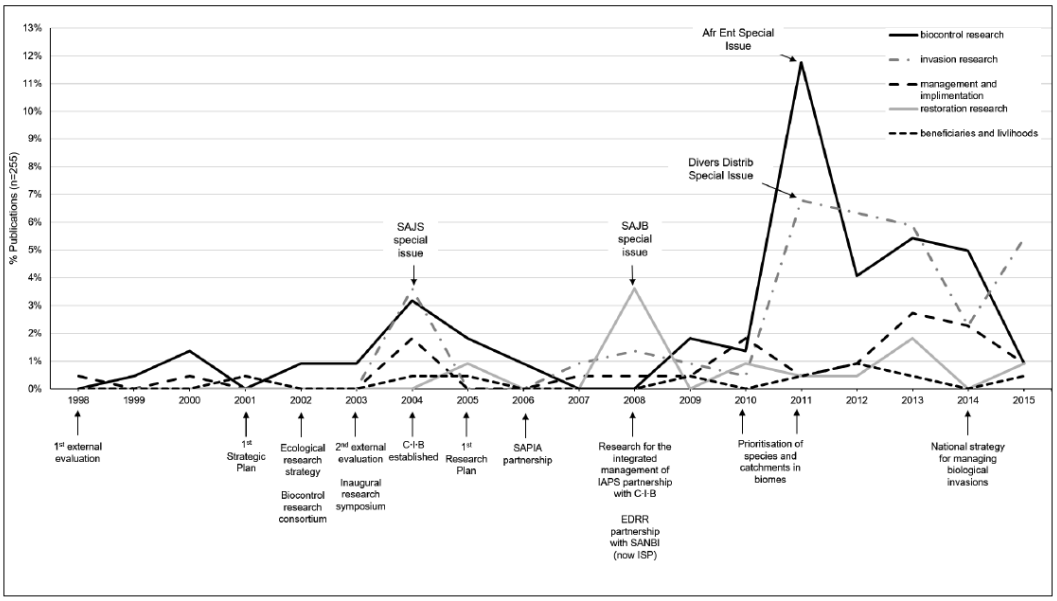


Figure 16. Timeline of events in relation to research output associated with Working for Water research themes (From Abrahams et al. 2019)

Integrative research approaches, such as transdisciplinarity, have the potential to improve interaction between science, policy and practice through improved stakeholder engagement and embedding research in societal processes, improving its relevance and practicability to knowledge users.

However, these approaches do not guarantee the automatic integration of scientific knowledge into policy or practice unless appropriate governance mechanisms are put in place. To be effective, social science research projects should be developed jointly by end-users from a wide range of

backgrounds and implementation contexts. In the case of Working for Water, turning its research investment into action requires the effective coordination of multiple partner institutions, their mandates, and resources — particularly where expectations and operational standards may differ.

"For science to have its desired impact and result in meaningful change, it must first be embedded in the society it seeks to influence. For that to happen the artificial distinction between science and society, and the scientist and the layperson, must be overcome," says Brent Abrahams, lead author of the study.

THE ROLE OF CORE RESEARCHERS IN SHAPING COLLABORATION NETWORKS AND RESEARCH FUTURES

Improving our understanding of the role researchers play in forming collaborative networks, can allow for more effective administration of the network to maximise research benefits. This includes the increased integration of knowledge across disciplinary boundaries, increased research productivity and innovation.

A study conducted by Brent Abrahams (C·I·B PhD student) and supervised by Karen Esler (C·I·B Core Team Member) and Nadia Sitas (Centre for Complex Systems in Transition) at Stellenbosch University, used social network analysis to identify and explore the roles of researchers in shaping collaboration networks and associated research outputs funded by the Working for Water Programme (WfW, one of the Natural Resource Management Programmes, NRMP) since the 1990s (Abrahams *et al*. 2019; *Journal of Environmental Management* 229:27–37)

The study found that research co-funded by WfW is authored predominantly by a handful of core researchers. These core researchers are typically at the centre of a network or community and are highly connected — a result of their sustained research contributions, leadership and establishment in their fields (Figure 17). These core researchers typically benefitted from accumulative advantage — a phenomenon also known as the Matthew effect, where 'the rich get richer'. They often possess status, privileged social and technical insights that are desirable to newcomers seeking access to this information and acquire recognition within their field. Core researchers therefore gain greater productivity and credibility in their field, by forging new and reinforcing older collaborations. How they use their advantageous position can impact both the advancement of research and the careers of newcomers to the field.

Core researchers can leverage social and other resources (such as financial, technical, equipment, and expertise) in a way that could either encourage or inhibit integrative research and innovation. Established researchers therefore play a role, not only in building a knowledge base, but also in facilitating the integration of new knowledge and new collaborators. The value of highly connected researchers in boundary spanning activities between disciplines, and in linking subgroups of researchers in collaboration networks has been shown in several disciplines (including socio-ecological, natural resource management, research administration and organisational science). Such individuals can facilitate the integration of information across a large knowledge base. Through an

in-depth knowledge of specific disciplines and understanding of where certain expertise is held within their network, these individuals can mobilise collaborative efforts to achieve various objectives.

However, invasion science, like even the purest of sciences, is a 'social field' — with its own distribution of power, its monopolies, struggles, strategies, interests and profits. As such, the scientific field is a locus for competitive struggle amongst researchers and institutions for scientific authority. This competitive struggle has the potential to drive innovation, but also stall it if innovation were to come at the expense of sound science.

"If leading voices in invasion science and management are oblivious to the need for, or unwilling to participate in collaborative activities, they may knowingly or unknowingly stall any progress made in the discipline. This both in terms of research and capacity building," explains Brent Abrahams.

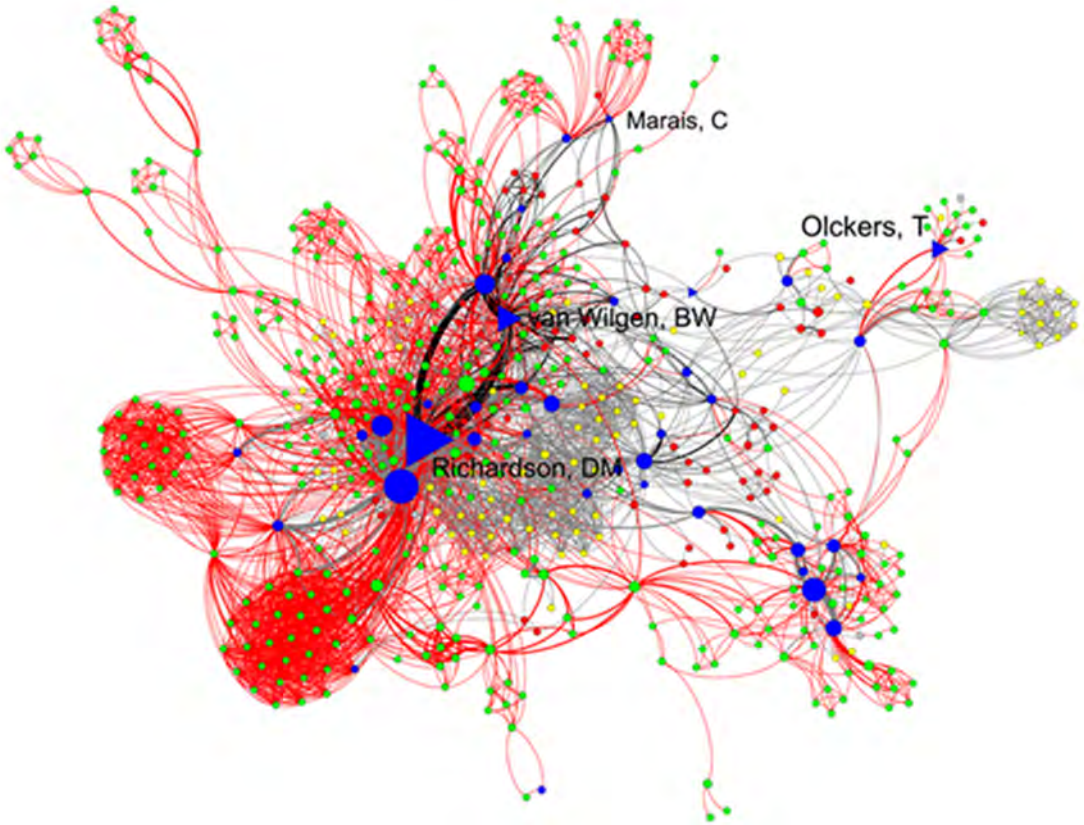


Figure 17. Blue nodes represent core authors, green- newcomers joining during and after 2011, red- authors left network before or during 2011, and yellow- authors with once off involvement in 2011. Link colour represents when links were formed. Wider links are indicative of a higher frequency of co-authorship. Black links were established between 1997-2004, grey- 2005-2011 and red- 2012-2017. Triangular nodes represent continuant authors in the 2004 peak. Links between red nodes and their neighbours represent ties that were established and then severed over the 1997 to 2011 period. The more articles co-authored by an author the larger the node (see Abrahams et al 2019)

2 EDUCATION AND TRAINING

2.1 International study abroad field course

During 2018, the C·I·B started planning a 'study abroad' field course that would increase the Centre's international exposure and draw in a network of early career researchers interested in invasion science. After initial discussions with Stellenbosch University's International Office, we were approached to host the 2019 iteration of an international field course for on behalf of Stellenbosch University. The Academic Consortium for the 21st Century (AC21) was established on June 24, 2002 at the International Forum 2002 hosted by Nagoya University, Japan, as an international network comprised of educational, research and industrial organizations throughout the world. Stellenbosch University is a member of AC21 and hosts a rotating field course annually. The course hosted by the C·I·B 'Invasion Science for Society: hands-on experience of environmental, social and economic impacts of alien species', took place during July 2019 and was convened and coordinated by Prof. John Measey.
The field course was open to C·I·B students as well as the international participants form AC21 consortium institutions. Seventeen students from six countries convened in the Western Cape for a week of theory and field experience centred on plant and animal invasions and the management thereof.

The course was designed to appeal to a wide range of participants from many backgrounds, whilst giving an African viewpoint on the issues around invasive species.


Banksia ericifolia

Invasion science playing cards

The course took the form of a series of workshops conducted by C·I·B staff together with two invited international guest lecturers. Workshop leaders took advantage of the local environment to make outings getting a handle on the different local challenges from invasions:

- Prof. John Wilson challenged course participants to locate and neutralise a nearby incursion of Australian *Banksia ericifolia;*


Participants in the AC21 course, Grootbos, July

- Prof. Tammy Robinson-Smythe took the students to the local coastal town of Gansbaai to explain how marine invasions are transported through ocean-going vessels;
- Prof. Karen Esler explained the complicated task of restoring local habitats after an invasion;
- Dr Sabrina Kumschick led a workshop on how to undertake risk assessment for invasive species; and
- Special guest lecturers, Prof. Jana Fried (Coventry University, UK) and Prof. Elizabeth Pienaar (University of Florida, USA) introduced participants to the role of social science and economics in managing invasive species.

The participants in the AC21 post-graduate course evaluated the course very positively and left South Africa with a much greater appreciation for the wicked problems involved in tackling invasive species. They returned home to cast fresh eyes on the problems in their own communities, equipped with novel insights and a new set of tools so that they can engage and work toward solutions. They also become part of a growing network of invasion scientists from around the world.

2.2 Student support programme

The support programme consists of a two-day On Boarding workshop for all our new students, and a second one-day workshop later in the year for all interested C·I·B students. The second workshop focusses on developing one or two specific skills relating to life as a post-graduate student. The programme also provides the opportunity for students to receive coaching towards specific goals that they would like to achieve.

In 2019 the On Boarding workshop was attended by 16 C·I·B students from various academic institutions across the country. The workshop focussed on orientating the students to the C·I·B's aims, structure, policies and procedures and then covered topics on non-academic skills which are

essential to student well-being and productivity. These topics included resilience, money management, time management, enhancing concentration and memory, living a balanced lifestyle and dealing with psychological challenges.

New students at the 'On Boarding' workshop, February 2019

The second workshop focussed on learning styles and project management. This workshop was held at Stellenbosch University and was attended by six, mostly local, students. In 2019, one student made use of the ongoing coaching opportunity and received three coaching sessions.

2.3 Science communication workshops

Due to cessation of our NRMP grant in 2017, there were no science communication workshops for students in 2019. They will be re-instated in 2020.

2.4 Under-graduate training

In the 2nd semester of 2019, 49 3rd year undergraduate students took the biological invasions module in the Department of Botany and Zoology (BDE345) at Stellenbosch University. This course aims to introduce students to invasion biology. It covers a variety of topics concerned with alien species including the processes governing their success, the impacts they have and the management of invasions. It is taught by three C·I·B Core Team Members: Tammy Robinson-Smythe, John Measey and Dave Richardson, with special guest lectures from various C·I·B Core Team, post-docs and staff from partner organizations. The course acts as a gateway into postgraduate studies in invasion biology for a growing proportion of C·I·B postgraduates, and in this way can be considered an important part of the C·I·B training pipeline.

2.5 Post-graduate and early career researcher training

Table 2. Post-graduate and post-doctoral researchers

	No.	%		No.	%
All supported students	63	100	All supported post-doctoral associates	14	100
Academic level					
Honours/4th year B. Agric.	4	6			
Masters	33	52			
PhD	26	41			
Gender			**Gender**		
Male	19	30	Male	7	50
Female	44	70	Female	7	50
Student demographics			**Student demographics**		
Black	41	65	Black	5	36
White	22	35	White	9	64
Funding level			**Funding level**		
Full	13	21	Full	8	57
Partial	17	27	Partial	1	7
Independent	33	52	Independent	5	36
Citizenship			**Citizenship**		
South African	59	94	South African	5	36
Foreign	4	6	Foreign	9	64
Ministerial targets for country of origin:			**Ministerial targets for country of origin:**		
South Africa	59	94	South Africa	5	36
SADC	1	2	SADC	1	7
Rest of Africa	1	1	Rest of Africa	0	0
Rest of World	2	3	Rest of World	8	57

2.6 Career development/alumni

Table 3. Current whereabouts of a selection of our alumni				
Name	**Qualification**	**Institution**	**Current position**	**Sector**
Dr Susan Canavan	PhD	Stellenbosch University	Post-doctoral associate, University of Florida	Academic / research
Dr Maria Castillo	PhD	Stellenbosch University	International Panel on Biodiversity and Ecosystem Services (IPBES)	Private sector / consulting
Dr Katelyn Faulkner	Post-doc	University of Pretoria	Researcher, SANBI	Government / implementing agency
Ms Joy Mangachena	Masters	Cape Peninsula University of Technology	PhD candidate, Griffith University, Australia	Studying further
Dr Sean Marr	Post-doc	SAIAB	Consultant	Private sector / consulting
Dr Ingrid Minnaar	PhD	Stellenbosch University	Post-doctoral associate, Stellenbosch University	Academic / research
Ms Ella Morran	Masters	Stellenbosch University	Customer Success Associate, Luno	Private sector / consulting
Dr Wolf-Christian Saul	Post-doc	Stellenbosch University	Post-doctoral associate, Free University, Berlin	Academic / research
Dr Madonna Vezi	Post-doc	University of KwaZulu-Natal	Hydrobiologist, City of Cape Town Scientific Services	Government / implementing agency
Dr Giovanni Vimercati	Post-doc	Stellenbosch University	Post-doctoral associate, Université de Fribourg	Academic / research

3 NETWORKING

3.1 Annual Research Meeting

The C·I·B held a very successful Annual Research Meeting on 14 and 15 November 2019. The meeting consisted of student presentations and two keynote addresses. Prof. Ary Hoffmann presented a keynote talk titled 'How can population genomics be used to improve our understanding of biological invasions?' To promote understanding of science communication, Prof. George Claassen, Public Editor and Ombudsman at News24 and Media24 spoke about 'Six impossible things before breakfast: why scientists should communicate through the media to counter pseudoscience'.

Each year the post-graduate students at masters and doctoral level compete for the C·I·B Student Travel Award, which is a substantial financial award to support a trip to a foreign laboratory, conference of training course. This year 46 students presented at the ARM and the best masters and doctoral presentations were identified by the C·I·B's international science advisors, Prof.s Laura Meyerson (University of Rhode Island, USA), Piero Genovesi (Institute for Environmental Protection and Research, Rome) and visiting fellow Ary Hoffmann (University of Melbourne, Australia).

Table 5. C·I·B student presentation awards

Masters		
Travel prize winner	Ncumisa Matam	How important are alien fishes in small dams in the Eastern Cape, if they are at all?
Runner up	Staci Warrington	Open relationships: The advantages of promiscuity in an Australian acacia and rhizobia mutualism
Special commendation	Nkosinathi Ntuli	Distribution and diet quality assessment of feral pigs (*Sus scrofa*) in South Africa
PhD		
Travel prize winner	Blair Cowie	The future of famine weed invasion: Will our controls be enough?
Runner up	Bheka Nxele	The effects of ecosystem restoration in cultural ecosystem services – Are we doing wrong by doing right?
Runner up	Anneke Schoeman	Keeping up with the co-invaders: The real story of two parasites that never let go of their invasive host

In addition to the C·I·B students, two students from Canada's University of Toronto, Scarborough, presented their work related to urban plants invasions, part of the ongoing collaboration between the C·I·B and Prof. Marc Cadotte of the Global Urban Biological Invasions Consortium. Although the Canadian students did not participate in the student award competition, it was interesting to hear about their work, gain an international perspective on urban plan invasions, and for the South African and Canadian students to interact.

3.2 Agreements with partner institutions

The C·I·B has memoranda of understanding with several organisations who work in the biodiversity conservation fields and can add to our perspectives on the environmental, economic and social impacts of invasive species and help us engage the diverse communities who are affected.

Table 4. Partner organisations with formal MOUs in place

Partner organisation	**Contact person**	**Partnership start date**
Western Cape Education Department	Mr Jean Goliath	June 2006
DEFF (formerly DEA) Natural Resources Management Programme	Mr Andrew Wannenburgh	February 2008
CapeNature	Dr Martine Jordaan and Dr Andrew Turner	June 2006

Table 4. Partner organisations with formal MOUs in place

Partner organisation	Contact person	Partnership start date
CAPE Invasive Alien Animal Working Group	Ms Julia Wood, Ms Chandre Rhoda	C·I·B was a founding partner in 2008
Honolulu Challenge	n/a	C·I·B became a signatory in December 2016
Soil Ecosystem Research Group	Dr Charlene Janion-Scheepers	C·I·B was a founding partner in 2011
City of Cape Town	Ms Julia Wood and Ms Chandre Rhoda	September 2012
Centre for Statistics in Ecology, the Environment and Conservation (SEEC), University of Cape Town	Prof. Res Altwegg,	October 2016
BirdLife South Africa	Dr Hanneline Smit-Robinson	April 2014
The Nature Conservancy	Ms Louise Stafford	February 2018
Institute of Botany, Academy of Sciences of the Czech Republic	Prof. Petr Pyšek	May 2012

3.3 Developing collaborations

3.3.1 Global Urban Biological Invasions Consortium (GUBIC)

Biological invasions cause many types of problems in urban areas, create special types of conflicts of interest, and require very different management interventions to those applied in natural ecosystems. Invasive species are likely to be more prevalent in cities than in nearby natural areas because of greater human activity, modified environmental conditions (e.g. gardens of alien plants provide obvious hotspots for the initiation of invasions), and high propagule pressure. Furthermore, attempts to manage them are often controversial because of the diversity of stakeholders in an urban context.

There is also a requirement under NEM:BA [national legislation that deals with invasions] for all organs of state (including municipalities) to provide invasive species management plans. There is an urgent need to develop the science base upon which such plans can be developed, and much scope exists for linking such studies with ongoing programmes in other parts of the world.

The C·I·B is a founding partner in the Global Urban Biological Invasions Consortium (GUBIC; https://cubes-labs.com/gubic/), which includes a consortium of more than 70 researchers from around the world, who are working on urban invasions. The C·I·B and GUBIC have compiled more than 500 urban datasets to analyse how geography, climate, and human history and trade influence the biodiversity of cities and especially their increasing similarity. The C·I·B and GUBIC have initiated eight different projects stemming from the aforementioned global analyses, from investigations into the roles urban ponds play in housing invasive species, to global comparisons of invasive species policies enacted by municipal governments, and to identifying invasive species management triggers in different socio-economic contexts. Beyond research projects, The C·I·B and GUBIC collaboration will result in several collaborative and training workshops on urban issues, rotated between Toronto, Canada and Stellenbosch.

C·I·B staff, associates and alumni at the launch of the GUBIC consortium in Canada

3.4 Developing collaborations - Afromontane Research Unit

As part of the C·I·B' s engagement with the Afromontane Research Unit at the Qwaqwa campus of the University of the Free State, C·I·B Director Dave Richardson is co-supervising a PhD student, Anthony Mapaura, who is registered for a thesis on "Determining the trajectory of graminoid invasions in southern Africa's mountains: the case of *Nassella*".

3.5 C·I·B fellowship programme

3.5.1 Andrew Robinson, CEBRA, Australia

Prof. Andrew Robinson from the Centre of Excellence for Biosecurity Risk Analysis (CEBRA) visited the C·I·B from 9-18 May. He ran a C·I·B workshop on risk analysis issues in invasion science, which was attended by C·I·B affiliates and staff from several partner organizations. He was also a keynote speaker at the National Symposium on Biological Invasions in Tulbagh in May 2019.

3.5.2 Quentin Groom, Meise Botanical Gardens, Belgium

Dr Groom visited Stellenbosch for five weeks at the end of 2019 (2 Nov – 10 Dec). His recent research interest has been towards creating repeatable data workflows for the analysis of biodiversity data, particularly using data on invasive species. Such workflows can harvest data, process it and output metrics and visualizations of biodiversity data with the minimum of manual intervention. Data workflows such as these can used to provide regular monitoring of invasive species, early warning and for horizon scanning for potential threats. They can also be used to

provide updated information in situations where data and analyses are rapidly evolving. This work foresees a future where modelling and analysis of invasive species is not done as a one-off scientific publication, but a continually updated process. During his fellowship, Quentin specifically investigated how to inform invasive species researchers and managers on the species interaction impacts of invasive species. This was done by combining data from the Global Biotic Interactions database (GLOBI) and with observation data from the Global Biodiversity Information Facility (GBIF). This produces output of species interaction networks for a region together with an indication of the prevalence of the interacting species in that region. A large amount of progress was made during his fellowship and there were many lively discussions on the subject with John Wilson, Sabrina Kumschick, John Measey, Cang Hui and Dave Richardson. The output of this research will be at least one publication during 2020.

Dr Groom also assisted with developing data standards as part of the National Status Report on Biological Invasions and in particular the national database of alien species that SANBI is developing as part of the reporting process (Zengeya, Rahlao, and colleagues at SANBI); he was a valuable contributor to the workshop on invasion frameworks (and is drafting a paper based on this, which is due out in late 2020) and ran a training workshop on "Biodiversity data management—the FAIR data principles" at Stellenbosch University. Finally, he continued to collaborate with Prof. Wilson as part of the sTwist and TDWG working groups (see e.g. Groom *et al*. 2019; Biodiversity Information Science and Standards 3:e38084).

3.5.3 Ary Hoffmann, University of Melbourne, Australia

Prof. Ary Hoffmann (Melbourne University) visited Prof. John Terblanche's research group for 10 days and spent time interacting with, sharing recent unpublished and published results and data, and discussing latest findings in diverse subjects, including invasion pathways of mosquitoes, evolution of abiotic stress resistance and dispersal ecology. Prof. Hoffmann also made himself available to a number of people and met with Prof. Clusella-Trullas, Dr Karsten, and several post-docs and students (Dr Quentin Willot, Ms Amy Collop) working on questions of evolutionary stress resistance or pest insect population genomics. Prof. Hoffmann and his hosts visited several potential field sites for future work. They also considered strategies for on-going collaboration and writing of grant applications on themes of mutual interest and ways to strengthen connections between our respective institutions.

During this period, John Terblanche and Ary Hoffmann sketched the framework for a paper on validating phenotypic plasticity estimates for climate change adaptation to enhance the robustness of inferences that can be drawn from such experiments. The paper is under review at *Current Opinion in Insect Science*.

3.6 Risk analysis workshop

As part of his fellowship visit to the C·I·B, on 10 May 2019, Prof. Andrew Robinson held a workshop with attendees from the C·I·B, various government departments (Departments of Environmental Affairs, Agriculture, Forestry and Fisheries, and Science and Innovation as well as Biosecurity SA) and SANBI on risk analysis with regards to regulations, specifically on alien and invasive species. He shared some valuable insights from his experiences with regulatory bodies, specifically in Australia and New Zealand.

Participants in the risk assessment workshop held on 10 May

3.7 National Symposium on Biological Invasions, May 2019

The 46th National Symposium on Biological Invasions took place between 15 and 17 May, 2019, at Waterval Country Lodge, Tulbagh. The meeting was jointly hosted by the C·I·B and SANBI. Three very interesting plenary lectures were given by Peter Lukey (DEFF: NRM), Jasper Slingsby (SAEON) and Andrew Robinson (CEBRA, Australia). In addition, nearly 100 presentations on invasive species were given to a large audience of participants. Social highlights included a student evening with fun and prizes led by C·I·B post-doc, Dr Mlungele Nsikani. As part of the programme at the National Symposium on Biological Invasions, Dr Nsikani also organized a workshop on the past, present and future of secondary invasions in South Africa. A paper from the workshop has been submitted to *South African Journal of Botany.*

3.8 Frameworks used in Invasion Science

Early in 2019, the C·I·B invited leading invasion scientists across taxonomic groups, environments, and disciplines to consider how the frameworks that have been developed in invasion science (from some of the most highly cited papers in the field) are useful for policy, management, and understanding. Notably we tasked them with investigating the practical issues that have arisen when applying the frameworks, and to draft manuscripts to highlight these (sometimes fundamental) challenges to the field and, where possible, to propose remedies. This developed into a specific challenge: "Can we provide recommendations for frameworks in invasion science to improve the usefulness of the frameworks for research, policy, or management, and so it is clear under which contexts the frameworks do and do not apply?"

To facilitate this, a workshop was convened over 3 days in November 2019 at the Spier Wine Estate near Stellenbosch, supported by the C·I·B, the NRF, Stellenbosch University, and the University of Freiburg. Forty attendees from 11 countries provided a vibrant atmosphere where we worked together on critically assessing the value of the frameworks. From this work, a special issue of the open-access journal *NeoBiota* is in progress (due to be published late in 2020), for which over 30 papers addressing specific problems are in various stages of development. Moreover, several broader papers are due to emerge (e.g. to construct a database of invasion frameworks, produce a genealogy, review the frameworks in light of desired properties for such frameworks, and recast specific frameworks in the light of the special issue and the needs for a practical tool that people can use for monitoring and reporting). Finally, the idea for a synthesis paper has emerged that, we feel, brings together the various frameworks into a single, simple model that will do much to resolve confusions and controversies in invasion science, and also, potential, strengthen the link to other fields working on global change.

4 INFORMATION BROKERAGE

4.1 Awards to team members

Emily Jones (PhD candidate, Nelson Mandela University) won the prize for the best full-length talk at the EMAPi15 conference in Prague, Czech Republic (9-13 September 2019), while Staci Warrington (MSc candidate, Stellenbosch University) was awarded the prize for the best flash talk at the same conference.

Blair Cowie (PhD candidate, University of the Witwatersrand) won two awards: first, for the best invasion biology poster presented at the 45th Conference of the South African Association of Botanists, University of Johannesburg, Johannesburg (9-11 January 2019) and at the 10th Annual Wits Cross-faculty Symposium, University of the Witwatersrand, Johannesburg, South Africa (3-4 September 2019).

Mmatsawela Ramahlo (PhD candidate, University of Pretoria) received a prize for the best international talk at the 11th International Symposium of Integrative Zoology at Massey University,

Auckland, New Zealand for her presentation titled "Land use and human population density are drivers of biological invasion: invasive *Rattus* vs indigenous *Micaelamys namaquensis*".

4.1.1 Kwame Nkrumah Award for Scientific Excellence

This section is extracted from an article published on the SU web site by Wiida Fourie-Basson, Science Faculty Media Officer, Stellenbosch University.

Prof. Dave Richardson was the recipient of the 2018 Kwame Nkrumah Award for Scientific Excellence, awarded early in 2019. This continental award is one of three awards made annually by the Scientific Commission of the African Union to recognise outstanding African scientists for their achievements, discoveries and innovations. One of Dave's major contributions to invasion science has been the thorough development and exploitation of new model systems for the elucidation of all the diverse perspectives that need to be considered to understand and manage invasive species. His contributions on the ecology of pines and Australian acacias are widely recognised as foundation studies in invasion science. Prof. Richardson has also contributed substantially to the formulation of practical guidelines for the improved management of invasions. The award was made at the Presidential Summit of the African Union in Addis Ababa in February 2019 by Abdel Fattah-el-Sisi, President of Egypt and Chair of the African Union for 2019.

4.2 Iimbovane Outreach Project

The C·I·B conducts general outreach (i.e. science engagement) on biological invasions as well as targeted learner and educator outreach through its Iimbovane Outreach Project. The highlights of these initiatives are shown below.

4.2.1 Not just the theory

Iimbovane's main objective is to teach learners about biodiversity and to make them aware of the impact of humans on the natural environment. The outreach project achieved this in 2019 by presenting several classroom lessons at partnership schools, hosting five 1-day workshops and a 5-day holiday programme.

Besides increasing the learners' content knowledge about biodiversity and invasive species, Iimbovane also helped the learners to develop important life-skills. The interactive approach used during all project's activities allowed the learners to 'learn, collaborate and solve problems' instead of simply being 'taught'. The practical activities of the workshops and holiday programme exposed the learners to problem solving as a group. By working in groups during the activities, the learners developed their abilities to learn from, to understand and to respect the opinions of learners from other schools and cultural backgrounds. This helped learners to develop collaboration and interpersonal skills. Workshops and holiday programmes also helped learners develop valuable communication skills, most notable when they had to present results from the practical activities both verbally and in writing. Learners who attended the project's workshops and holiday programmes also received

valuable training in the use of computer programmes such as Excel and PowerPoint. Many of these learners had never worked on computers before, but will be now be able to prepare class assignments and presentations using the computer skills they gained during their participation in Iimbovane.

Feedback from learners demonstrated the value of these skills learnt:

"*I learned how to use a microscope and computer because I've never used one before*."

"*How to use a Power Point and that team work is important and to count the different plant species*."

"*I learned important computer skills and a lot about invasive alien species which I never understood*."

4.2.2 Engaging future educators

In 2019, the Iimbovane project team invited undergraduate and postgraduate students from the Stellenbosch University's Department of Education to assist with the 5-day holiday programme. These students are future Life Science educators and by being part of the workshop, they walked away with the know-how of planning and implementing a practical investigation on biodiversity.

This initiative proved to be very valuable for the students, as is evident from their feedback:

"As a future educator specialising in Natural Sciences, the Iimbovane biodiversity workshop has equipped me with new insight and experience in field trips that forms a crucial part of science education. I also gained experience in doing practical activities with learners outside of the normal classroom setting. I was able to practice teaching and learning strategies and develop new strategies while assisting learners with developing skills in data capturing (computer skills), doing presentations and field work. I also had the opportunity to gain knowledge in the field of marine biology, which increased my awareness and appreciation thereof. Other than assisting with workshop content, I was able to develop my skills in conflict management, critical thinking and facilitating group activities."

4.2.3 For the classroom

The Iimbovane project continued with the development of educational resources. In 2019, the team developed a resource pack consisting of cards that provides learners with the challenge to organise the cards based on their knowledge and understanding of invasive alien species. The cards are fitted with prompts to assist educators with classroom discussions about introductions and pathways, impacts and current control measures of invasive alien species.

4.3 Further outreach activities

Throughout 2019, the project has collaborated with various groups and communities outside the normal scope, for example, the project collaborated with the Cape Leopard Trust on a workshop for a group of primary school learners. The project also hosted one of the Western Cape Environmental

Education Forum's quarterly meetings and the Iimbovane team was invited to do presentations at non-partnership schools. Iimbovane engaged with the wider public through exhibits at open days and expos. In August 2019, Iimbovane was again a big hit among visitors at the annual SANBI/WCED Biodiversity careers expo at the Herold Porter Botanical Garden, Bettys Bay.

In December 2019, the Iimbovane project team share their experiences and the lessons learnt at the *South African Higher Education Community Engagement Forum Conference* at the University of Mpumalanga.

The Iimbovane project was also mentioned in a *South African Journal of Science* article, which highlighted the project's importance and contribution to the field of citizen science in the South Africa. The article can be viewed at: http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532019000400009.

4.3.1 Cell C Take a Girl Child to Work Day

In May 2019, a group of twelve Grade 11 learners from the Manzomthombo Secondary School visited the C·I·B as part of the Cell C Take a Girl Child to Work Day. This annual initiative provides young girls with the necessary information to equip them for making better, informed choices about their future careers. The day's activities allowed learners to see the variety of roles within an academic and research institution such as the C·I·B. The group met several women in biological sciences, in professions such as post-doctoral associates, senior researchers and lecturers, and management staff. The day also included a tour of the campus and the Stellenbosch University library.

4.3.2 Science Café

The C·I·B was approached by the Faculty of Science at Stellenbosch University to host a Science Café at the Woordfees, a large arts festival held annually in Stellenbosch and supported by Stellenbosch University. Science Café Stellenbosch aims to promote the public discussion of science in an relaxed social setting. On 7 March 2019, C·I·B Core Team Member Brian van Wilgen, C·I·B Associate David Le Maitre (CSIR) and World Wildlife Fund hydrologist Christine Colvin were panel members and the discussion was chaired by C·I·B associate Dave Pepler. The audience was treated to a lively discussion about the impacts of invasive plants such as pine trees and Australian acacias on the reduction of surface water runoff in South Africa. The discussion also addressed what is currently being done to address this problem and the successes of these efforts.

4.4 Media highlights

In 2019, the C·I·B's research was covered by both local and international media. A more comprehensive list of media mentions can be found in Appendix 1. However, there are highlights that deserve special mention.

In August 2019, C·I·B Associate Jaco Le Roux and colleagues made waves in the media and attracted interest from both local and international media. The paper, which was published in *Current Biology*, confirmed the extinction of 79 plants in South Africa's three biodiversity hotspots. The paper has led to numerous articles on online news platforms including Times Live, Cape Argus, Eyewitness News, Science Daily, Daily Mail and News24. The paper featured in several articles in the print media including Die Burger, The Citizen, Cape Times and Cape Argus. The current levels of biodiversity loss received further attention through a television interview with C·I·B post-doc and co-author, Dr Heidi Hirsch, on eNews Channel Africa and through radio interviews with Hirsch and Le Roux on Cape Talk and Radio Sonder Grense Plus.

Research conducted by C·I·B post-doc Mlungele Nsikani and co-workers led to several media mentions in 2019. The research, which was published in the *South African Journal of Botany*, found that secondary invasive species can flourish when primary invaders, such as acacias, have been removed from an area through clearing activities. Articles about these findings appeared on online platforms including Cape Times and Eikestadnuus. Dr Nsikani was also the guest of a radio interview on Cape Talk.

A paper published by C·I·B Core Team Member John Measey in October 2019 highlighted the importance of establishing more research networks between the BRICS countries (Brazil, Russia, India, China and South Africa) to curb the spread of invasive species within and outside of these countries. The paper, published in *PLoS Biology*, drew attention from national and international science media platforms and led to article on online news sites such as Phys.org, Eureka Alert, Bizcommunity and The Conversation. The paper received further exposure through a radio interview with Prof. Measey on Smile FM.

C·I·B post-doc Nitya Mohanty received several mentions in the media for his research on the role of the global amphibian trade in the spread of invasive alien species. His paper, published in Biological Conservation, featured in articles on online news sites including All Africa, eNews Channel Africa, The Hindu and The Conversation. Dr Mohanty was also interviewed on the television channel eNews Channel Africa.

In 2019, C·I·B Director David Richardson was awarded the prestigious African Union Kwame Nkrumah Award for Scientific Excellence (see section 4.5.1, above). This achievement received attention from various online websites such as Pan African News, Anadolu Agency, Academy of Science of South Africa (ASSAf) and the Department of Science and Innovation.

4.5 Web-based services and social media

Table 6. IRSS, web site and social media statistics

<table>
<tr><td>Instrument</td><td>Number of interactions</td></tr>
<tr><td>Information retrieval and submission system
https://ir.sun.ac.za/cib/</td><td>235 items were submitted to the IRSS during the reporting year</td></tr>
<tr><td>Web page
www.sun.ac.za/cib</td><td>17 879 unique visitors
29 440 unique page views

Africa 8601 | Oceania 386
Europe 2350 | South America 388
North America 4042 | Central America 11
Asia 915 | Other 1186</td></tr>
<tr><td>C·I·B – Facebook
centreforinvasionbiology</td><td>1245 follows in total
44 posts
702 viewers per post (average)

The C·I·B's Top Five posts:
<table><tr><th>Date</th><th>C·I·B nugget</th><th>People reached</th></tr><tr><td>1 Feb</td><td>Congratulations to our director, Prof. Dave Richardson, who is the recipient of the 2018 Kwame Nkrumah Award for Scientific Excellence!</td><td>5600</td></tr><tr><td>19 Mar</td><td>A study conducted by Brent Abrahams (C·I·B PhD student) and supervised by Prof. Karen Esler…</td><td>2400</td></tr><tr><td>15 Jan</td><td>Project Manager position available at SAIAB. National surveys of Nile Tilapia distribution.</td><td>1700</td></tr><tr><td>18 Feb</td><td>Arne Witt (Centre for Agriculture and Biosciences International, Kenya), Ross Shackleton (Former C·I·B PhD student and post-doc) and…</td><td>1400</td></tr><tr><td>7 Oct</td><td>Guttural toads (Sclerophrys gutturalis) have been invasive in Mauritius and Reunion for nearly 100 years…</td><td>1100</td></tr></table></td></tr>
<tr><td>C·I·B – Twitter
@invasionscience</td><td>3738 total Tweets
1133 followers
Per day average: 924 impressions | 3 link clicks | 2 retweets | 7 likes | 1 reply</td></tr>
</table>

5 SERVICE PROVISION

5.1 National Status Report

In terms of South African legislation (regulations under the National Environmental Management: Biodiversity Act, Act 10 of 2004), the South African National Biodiversity Institute (SANBI) has to submit a report on the status of biological invasions, and the effectiveness of control measures and regulations, to the Minister of Environmental Affairs every three years. The C·I·B provided vital support to the team from SANBI that drafted the first report (reported in 2018), which involved 37 contributors from 14 organisations. The status report was a global first, as no other nation has

assessed all aspects of biological invasions at a national level. It covers *pathways* of introduction and spread, the extent, abundance and impact of individual *species*, and the richness and abundance of invasive species in particular *sites*, and their collective impact on those sites. In addition, the report assesses the effectiveness of *control measures*, and the effectiveness of *regulations* on the control of alien species. In order to report on these aspects, the team developed a set of indicators for assessing status at a national level. The framework of indicators is intended to facilitate the inclusion of biological invasions in environmental reporting at national and international levels. Key high-level findings included that approximately seven new alien species have recently been recorded as establishing annually at a national level; that over 100 species were already having major impacts; that 1.4% of the country was experiencing major impacts; and that management success levels were around 5.5%. The level of confidence in these estimates was low, however, because the data on which they were based were scattered and incomplete. The gaps identified in the status report, and especially those relating to improving the levels of confidence associated with the indicators, provides a useful framework for prioritizing research projects that can improve future reports.

The visit of Quentin Groom from Meise Botanical Gardens in Belgium, and funded by the C·I·B, provided support to the National Status Report drafting team in providing expertise on data standards for invasive species monitoring going forward. As with the first landmark report, the C·I·B continues to contribute to the second National Status Report, which is currently being written.

6 GENDER IMPACT

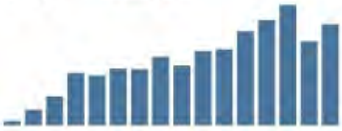
15 out of 18 graduates in 2019 were female, showing the impact on production of female South African scientists (73% of the graduates were South African). In terms of the impact of our research, invasions, particularly of plants in rural areas disproportionately affect women as they are frequently heads of households. Research from the Centre that is taken up by municipalities and the national government programmes to remove invasive plant species (e.g. Working for Water, Working on Fire and Land Care) benefits clearing programmes in rural areas and on farms. Unfortunately, the take-up of research findings is not uniform, and we are always working on better ways to ensure that government takes up our research findings to improve its practices and policy.

7 RETURN ON INVESTMENT

Return on investment is an accounting measure that is often measured in commercial firms with shareholders, as the ratio between earnings and total assets. There are significant difficulties in quantifying ROI for an entity such as the C·I·B, which essentially in the public interest and does not receive ‘reward’ for its products (students, research products, community interactions etc.). however, one of the measures of the return on investment in STEM fields, is citation frequency and quality. The C·I·B's H-index rose to 97 from 89 in December 2018, and citations rose as shown in the figures below. This together with the human capacity built (Table 3) and the collaborative enterprises outlined in Tables 4 and 9 encapsulate a measure of ROI for the Centre.

Total Publications

1,846 Analyze



2000 2019

h-index

97

Average citations per item

27.96

Sum of Times Cited

51,623

Without self citations

43,100

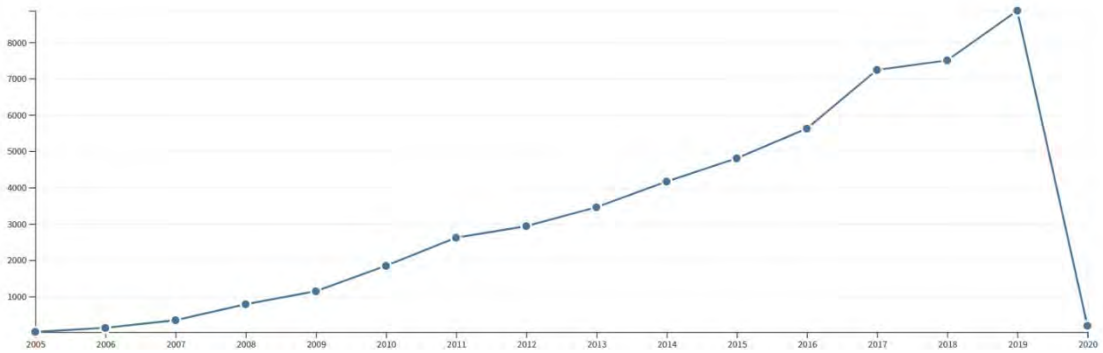
Citing articles

30,220 Analyze

Without self citations

28,816 Analyze

Sum of Times Cited per Year



Citation report for the C·I·B (2004-2019). Downloaded 20 January 2020; http://apps.webofknowledge.com.

8 GOVERNANCE AND ORGANISATIONAL STRUCTURE

8.1 Steering Committee

Table 7. The Steering Committee of the C·I·B

Name	Affiliation	Role
Prof. Eugene Cloete	Stellenbosch University	Ex officio (Vice Rector, Research, Innovation and Postgraduate Studies)
Prof. Louise Warnich	Stellenbosch University	Ex officio (Dean of Science)
Prof. Dave Richardson	Centre for Invasion Biology, Faculty of Science, Stellenbosch University	Ex officio (Director)
Dr Sarah Davies	Centre for Invasion Biology, Stellenbosch University	Ex officio
Dr Makobetsa Khati	Research Chairs and Centres of Excellence, National Research Foundation	NRF Representative
Mr Nathan Sassman	Centres of Excellence Programme, National Research Foundation	NRF Representative (alternate)
Prof. Michael Somers	Mammal Research Institute, University of Pretoria	Core Team Representative
Prof. John Donaldson	Biodiversity Research, Assessment and Monitoring, South African National Biodiversity Institute	Industry Representative
Mr Ahmed Khan	Strategic Services, DEFF Natural Resources Management Programme	Industry Representative
Dr Angus Paterson	South African Institute for Aquatic Biodiversity	Industry representative
Prof. Sheona Shackleton	African Climate and Development Initiative (ACDI)	Social Science Advisor
Prof. Piero Genovesi	ISPRA Institute for Environmental Protection and Research, Italy	International Science Advisor
Prof. Laura Meyerson	Department of Natural Resources Science, The University of Rhode Island, USA	International Science Advisor

8.2 Core team members

Table 8. C·I·B core team members

Name	Institute	Race	Gender	Citizenship#	% Time in CoE	NRF rating
Prof. Marcus Byrne	Wits	White	Male	SA	10	C
Prof. Chris Chimimba	UP	Black	Male	SA	25	C
Prof. Susana Clusella-Trullas	SU	White	Female	SA	50	C
Dr Sarah Davies	SU	White	Female	SA	100	Unrated
Prof. Colleen Downs	UKZN	White	Female	SA	10	C
Prof. Karen Esler	SU	White	Female	SA	10	C
Prof. Stefan Foord	UniVen	White	Male	SA	20	C
Prof. Llewellyn Foxcroft	SANParks	White	Male	SA	20	C
Prof. Cang Hui	SU	White	Male	SA	40	B
Dr Sabrina Kumschick	SU	White	Female	Switzerland	90	C
Prof. John Measey	SU	White	Male	UK	100	C
Dr Thabiso Mokotjomela	SANBI	Black	Male	SA	15	Unrated

Name	Institute	Race	Gender	Citizenship#	% Time in CoE	NRF rating
Dr Sebataolo Rahlao	SANBI	Black	Male	SA	10	Unrated
Prof. Dave Richardson	SU	White	Male	SA	100	A
Prof. Mark Robertson	UP	White	Male	SA	40	C
Prof. Tammy Robinson-Smythe	SU	White	Female	SA	40	C
Dr Sheunesu Ruwanza	Rhodes	Black	Male	SA	30	Y
Prof. Michael Somers	UP	White	Male	SA	10	C
Prof. Peter Taylor	UniVen	White	Male	SA	10	B
Prof. John Terblanche	SU	White	Male	SA	15	B
Prof. Olaf Weyl	SAIAB	White	Male	SA	20	B
Prof. John Wilson	SANBI	White	Male	SA	80	B
Dr Tsungai Zengeya	SANBI	Black	Male	SA	40	Y
Emeritus core team members:						
Prof. Charles Griffiths	UCT	White	Male	SA	10	B
Prof. Brian van Wilgen	SU	White	Male	SA	90	B

#'SA' denotes SA citizen or permanent resident.

8.3 Research associates

Table 9. C·I·B research associates

Full name	Affiliation
Dr Mhairi Alexander	University of the West of Scotland, UK
Prof. Tim Blackburn	University College London, UK
Dr Ryan Blanchard	Natural Resources and the Environment, CSIR
Dr Jane Carruthers	Private (retired academic)
Prof. Franz Essl	University of Vienna, Austria
Dr Mirijam Gaertner	Nürtingen-Geislingen University of Applied Science, Germany
Dr Sjirk Geerts	Cape Peninsula University of Technology
Prof. Jan Giliomee	Department of Botany and Zoology, Stellenbosch University (Emeritus Professor)
Prof. Patricia Holmes	Cape Ecological Services
Dr Brian Huntley	Private (retired researcher)
Dr Michelle Jackson	Imperial College London, UK
Dr Charlene Janion-Scheepers	Iziko South African Museum
Dr Martine Jordaan	CapeNature Scientific Services
Prof. Christoph Kueffer	ETH Zurich, Switzerland
Dr David Le Maitre	Natural Resources and the Environment, CSIR
Prof. Jaco Le Roux	Department of Biological Sciences, Macquarie University, Australia
Dr Candice Lyons	Plant Protection Research Council (PPRI), ARC
Mr Dave Pepler	Stellenbosch University
Prof. Petr Pyšek	Institute of Botany, Academy of Sciences of the Czech Republic
Prof. Tony Ricciardi	Redpath Museum, McGill University, Canada
Dr Ross Shackleton	University of Lausanne, Switzerland
Dr Nicola Van Wilgen	Global Change Scientist, South African National Parks
Dr Darragh Woodford	University of the Witwatersrand

8.4 Support staff employed by the C·I·B

The table below shows the staff who were employed in the Centre in 2019.

Table 10. C·I·B staff

Name	Institute	Position	Gender	Race
Ms Lorraine Cilliers*	SU	Personal Assistant to the Director	Female	White
Ms Jean Lategan**	SU	Personal Assistant to the Director	Female	White
Ms Karla Coombe-Davis	SU	Principal Technical Officer	Female	White
Dr Sarah Davies	SU	Research Manager	Female	White
Ms Dorette Du Plessis	SU	Iimbovane Programme Manager	Female	White
Ms Kerryn Grenfell#	UP	Northern Hub Technical Officer	Female	White
Ms Megan Mathese*	SU	Molecular Lab Manager	Female	Coloured
Ms Suzaan Kritzinger-Klopper	SU	Chief Technical Officer	Female	White
Dr Sabrina Kumschick	SU	Researcher	Female	White
Dr Elrike Marais	SU	Research and Project Manager	Female	White
Prof. John Measey	SU	Senior Researcher	Male	White
Mrs Christy Momberg	SU	Management Assistant	Female	White
Ms Rhoda Moses*	SU	Administrative Officer	Female	Coloured
Ms Londiwe Msomi	SU	Education Outreach Officer	Female	African
Ms Erika Nortje	SU	Ecophysiology Lab Manager	Female	White
Prof. Dave Richardson	SU	Distinguished Professor	Male	White
Ms Sophia Turner*	SU	Iimbovane Technical Assistant	Female	White
Ms Mathilda Van Der Vyver	SU	Administrative Officer	Female	White
Prof. Brian Van Wilgen	SU	Professor	Male	White

#Position jointly supported by the C·I·B and the University of Pretoria

*Resigned during the year

**Joined during the year

Please see Appendix 1 for student and post-doc lists

9 STAGE PROGRESS AGAINST SERVICE LEVEL AGREEMENT

This CoE is currently in **Stage 6** (2015-2019).
This is the last year of the stage and thus constitutes a Gate Review.

Timeframes

The pending Gate review (Gate 6) shall take place during February or March 2020

Two COE Steering Committee (virtual or real) meetings should take place per annum during this Stage, typically during March and November of each year

2015: The Steering Committee met on 18 March and 19 October 2015
2016: The Steering Committee met on 18 March and 27 October 2016
2017: The Steering Committee met on 24 March and 26 October 2017
2018: The Steering Committee met on 29 March and 14 November 2018
2019: The Steering Committee met on 11 March and 28 October 2019

Activities related to the Current Stage

The COE shall provide to the NRF a list of students that are being supported by the Centre by end April of each year. Additional students can be appended to this list as and when they arrive

2015: Student list provided and entered onto the NRF online system as requested
2016: Student list provided and entered onto the NRF online system as requested
2017: Student list provided and entered onto the NRF online system as requested
2018: Student list provided and entered onto the NRF online system as requested
2019: Student list provided and entered onto the NRF online system as requested

The COE will publish 'vignettes' (formerly termed 'nuggets') of information on its website and provide these at six-monthly intervals to the NRF.

2015: Vignettes were published regularly on the C·I·B web site, Facebook page and Twitter feed and sent in batches to the NRF on 1 April, 29 July and 1 November
2016: Vignettes were sent to the NRF on 7 June, 5 July 2016 and 28 Feb 2017
2017: Vignettes were sent to the NRF on 13 April 2017
2018: Vignettes were sent to the NRF on 12 April, 17 July, 5 October 2018 and 18 January 2019
2019: Vignettes were sent to the NRF on 1 April, 25 July, 4 October 2019 and 7 January 2020

Financial responsibilities

The COE shall present an audited set of financial statements annually at the March Steering Committee meeting reflecting the financial situation of the COE during the previous financial year

2015: The 2015 financial statements were presented to the Steering Committee on 18 March 2016
2016: The 2016 financial statements were presented to the Steering Committee on 24 March 2017
2017: The 2017 financial statements were presented to the Steering Committee on 29 March 2018
2018: The 2018 financial statements were presented to the Steering Committee on 11 March 2019

2019: The 2019 financial statements will be presented to the Steering Committee on 26 March 2020

The COE shall submit monthly cash-flow statements within 15 days of the end of each calendar month according to the NRF template for cash flow reporting

2015: Cash flow statements submitted on a quarterly basis as requested in the COE Handbook (2014 version)

2016: Cash flow statements were submitted on a quarterly basis as requested

2017: Cash flow statements were submitted on a quarterly basis as requested

2018: Cash flow statements were submitted on a quarterly basis as requested

2019: Cash flow statements were submitted on a quarterly basis as requested

Reports due in this Stage

The COE shall submit an Annual Progress Report by no later than end March each year, including the Stage 6 Gate Review Documentation by no later than March 2020 to be reviewed by the COE Steering Committee

2015: The annual report for 2015 was approved by the Steering Committee on 18 March 2016

2016: The annual report for 2016 was approved by the Steering Committee on 24 March 2017

2017: The annual report for 2017 was approved by the Steering Committee on 29 March 2018

2018: The annual report for 2018 was approved by the Steering Committee on 11 March 2019

2019: The annual report for 2019 will be presented to the Steering Committee on 26 March 2020

The COE shall submit a Statement of Compliance by no later than March 2020 referring to Stage 6

2015: The statement of compliance was signed by the Steering Committee on 18 March 2016

2016: The statement of compliance was signed by the Steering Committee on 24 March 2017

2017: The statement of compliance was signed by the Steering Committee on 29 March 2018

2018: The statement of compliance was signed by the Steering Committee on 11 March 2019

2019: The statement of compliance will be signed by the Steering Committee on 26 March 2020

Standard Output Targets per annum in the Current Stage

Total number of students supported ≥ 60 on average per annum

2015: 67 students supported

2016: 71 students supported

2017: 71 students supported

2018: 60 (excluding post-docs)

2019: 63 (excluding post-docs)

Phase average: 66 (total 322)

Women students ≥ 50% of all students on average per annum

2015: Women students 54% of student group

2016: Women students 56% of student group

2017: Women students 70% of student group
2018: Women students 70% of student group
2019: Women students 70% of student group (44/63)
Phase average: 64%

Black students ≥ 50% of all students on average per annum
2015: Black students 52% of student group
2016: Black students 46% of student group
2017: Black students 46% of student group
2018: Black students 58% of student group
2019: Black students 65% of student group (41/63)
Phase average: 53%

Number of social science students ≥ 2 on average per annum
2015: Two social science students supported (i.e. registered in the social sciences; several other students and post-doctoral associates engaged in projects that ask socially-relevant questions and use social science methods)
2016: Two social science students supported (Thomas Stielau, MA; Brent Abrahams, PhD)
2017: One student registered for a social science degree (Thomas Stielau, MA, UCT) was supported. Another two students have projects that explicitly address social science issues (Sinazo Ntsonge, MSc, Rhodes University and Brent Abrahams, PhD, Stellenbosch University).
2018: Two students were registered for social science focused degrees: Sinazo Ntsonge (PhD candidate, Rhodes) and Brent Abrahams (PhD candidate, SU)
2019: Two students were registered for social science focused degrees: Sinazo Ntsonge (PhD candidate, Rhodes) and Brent Abrahams (PhD candidate, SU)
Phase average: 2

Average duration of submitted Masters degrees (post Honours) ≤ 2.5 years at end of stage
2015: 2.25 years
2016: 2.7 years
2017: 2.6 years
2018: 2 years
2019: 2.9 years
Phase average: 2.5 years

Average duration of submitted PhD degrees (post Masters) ≤ 3.5 years at end of stage
2015: 4.4 years
2016: 3.8 Years
2017: 4 years
2018: 4.7 years
2019: 4.3 years

Phase average: 4.2 years

Average duration of submitted PhD degrees (upgraded from Masters) ≤ 5 years at end of stage
2015: 4.4 years
2016: None completed in 2016
2017: 4.8 years
2018: 4 years
2019: 3.9 years
Phase average: 4.3 years

Post-doctoral researchers ≥ 10% of all students at end of stage
2015: Post-doctoral associates made up 20% of the students and post-doctoral associates supported
2016: Post-doctoral associates made up 18% of the students and post-doctoral associates supported
2017: Post-doctoral associates made up 15% of the students and post-doctoral associates supported
2018: Post-doctoral associates made up 15% of the students and post-doctoral associates supported
2019: Post-doctoral associates made up 19% of the students and post-doctoral associates supported (14/75)
Phase average: 17%

Each core team member must undertake at least one scientific review per annum on behalf of the NRF (postal peer review process or panel)
2015: 20 reviews performed
2016: 19 reviews performed
2017: 33 reviews performed
2018: 29 reviews performed
2019: 22 reviews performed
Phase average: 25 p.a.

Number of patents ≥ 1
2015: 0
2016: 0
2017: 0
2018: 0
2019: 0
Phase total: 0

Number of peer reviewed publications ≥ 85 on average per annum

2015: 178

2016: 201

2017: 216

2018: 162

2019: 190

Phase average: 189

Number of peer reviewed publications ≥ 2 with an impact rating of ≥ 15 on average per annum

2015: 2

2016: 1

2017: 4

2018: 1

2019: 5

Phase average: 3

Number of peer reviewed publications ≥ 20 with an impact rating of ≥ 4.0 on average per annum

2015: 33

2016: 36

2017: 47

2018: 43

2019: 51

Phase average: 42

Number of national conference presentations ≥ 30 on average per annum

2015: 41 (2 plenary/keynote; 34 oral; 5 poster)

2016: 38 (6 plenary/keynote; 25 oral; 7 poster)

2017: 90 (6 plenary/keynote; 75 oral; 9 poster)

2018: 56 (4 plenary/keynote; 43 oral; 9 poster)

2019: 84 (no plenary/keynotes; 74 orals; 10 posters)

Phase average: 62

Number of international conference presentation ≥ 10 on average per annum

2015: 26 (2 plenary/keynote; 22 oral; 2 poster)

2016: 40 (7 plenary/keynote; 26 oral, 7 poster)

2017: 42 (6 plenary/keynote; 27 oral; 9 poster)

2018: 38 (7 plenary/keynote; 28 oral; 3 poster)

2019: 42 (4 plenary/keynotes; 33 orals; 5 posters)

Phase average: 38

Number of joint venture student training initiatives ≥ 20 on average per annum
2015: 67 (including co-supervisions and UCT Humanities students)
2016: 58 (including co-supervisions)
2017: 115 (including co-supervisions)
2018: 70 (including co-supervisions)
2019: 51 (including co-supervisions)
Phase average: 72

Number of local conferences organized ≥ 2 at end of stage
2015: One meeting organised (Conservation in the Cape Floristic Region, 13 April 2015)
2016: Two meetings organised (43rd Annual Research Symposium on the Management of Biological Invasions in South Africa, Goudini Spa, 18-20 May 2016, co-hosted with SANBI ISP; workshop on 'Biological invasions in urban areas: understanding the problems and identifying research priorities' held at University of Pretoria, 25-26 August 2016, by the Northern Hub)
2017: The C·I·B held a joint workshop with the South African Centre for Epidemiological Modelling and Analysis (SACEMA) on 'Integrating techniques in invasion biology and epidemiology for practical management of species invasions and emerging infectious diseases'.
2018: A team workshop on 'Biological invasions in South Africa: trends and implications for management' was held prior to the ARM on 7 November 2018
2019: National Symposium on Biological Invasions, 15–17 May 2019. Waterval Country Lodge, Tulbagh, Western Cape.
Phase total: 6

Number of international conferences organized ≥ 2 at end of stage
2015: Two meetings organised (Evolutionary dynamics of tree invasions: drivers, dimensions, and implications for management; Functional responses as a tool in invasion ecology, 9-10 November 2015)
2016: One meeting organised (Non-native species in urban environments: Patterns, processes, impacts and challenges, Lanzerac, Stellenbosch, 7-9 November 2016)
2017: One meeting organised (Invasion syndromes – moving towards generalizations in invasion science, Stellenbosch University, 6-8 November 2017).
2018: International workshop on 'The importance of international networks in invasion science' to establish an invasion science network among BRICS countries
2019: International workshop on 'Frameworks used in Invasion Science', 11-13 November 2019. Spier Conference Centre, Cape Town.
Phase total: 6

Special Output Targets for the Current Stage

At least one full COE team activity per annum
2015: The C·I·B held both a Core Team Meeting (Tuesday 14 July 2015 at SAIAB, Grahamstown) and an Annual Research Meeting (12 and 13 November 2015, at Stellenbosch University). Although a

few core team members were unable to attend due to other commitments, both meetings were well-attended.
2016: A mid-year Core Team Meeting was held on 18 May 2016 at Goudini Spa, and 18 members attended (six were not able to attend). The Annual Research Meeting was held on 10 and 11 November at Stellenbosch University and was well attended by the Core Team, science advisors, students and post docs as well as research associates, guests and partners of the Centre.
2017: 151 people attended the C·I·B's thirteenth Annual Research Meeting held in Stellenbosch on 9-10 November 2017; two core team members were unable to attend.
2018: 132 people attended the 14th Annual Research Meeting held in Stellenbosch on 8-9 November 2018 ARM; one core team member was not able to attend.
2019: 122 people attended the C·I·B's 15th Annual Research meeting held in Stellenbosch on 14-15 November; two core team members were not able to attend the meeting.

Successful continuation of Iimbovane Outreach Project to schools in the WCED region
2015: 28 participating schools (17 rural/11 urban of which 26 are serving previously-disadvantaged communities; 18 full participation/10 subscription)
2016: 28 participating schools (17 rural/11 urban of which 26 are serving previously-disadvantaged communities; 18 full participation/10 subscription).
2017: 23 participating schools (16 rural/7 urban of which 21 are serving previously-disadvantaged communities; 17 full participation/6 subscription).
2018: 23 participating schools (16 rural/7 urban of which 21 are serving previously-disadvantaged communities; 17 full participation/6 subscription)
2019: 23 participating schools (16 rural/7 urban of which 21 are serving previously-disadvantaged communities; 17 full participation/6 subscription)

Appendix 1. Outputs

Research

Books

Book chapters

Coetzee, J.A., Hill, M.P., Hussner, A., Nunes, A.L. and Weyl, O.L.F. (2019). Invasive Aquatic Species. In: *Freshwater Ecology and Conservation: Approaches and Techniques* Hughes, J.M.R. (ed.). Oxford University Press, New York, NY 10016 USA. pp. 338-358.

Seymour, C. and Joseph, G. (2019). Ecology of Smaller Animals Associated with Savanna Woody Plants: The Value of the Finer Details. In: *Savanna Woody Plants and Large Herbivores.* Scogings, P.F. and Sankaran, M. (eds.). John Wiley & Sons, Inc, Hoboken, NJ, USA. pp. 183-212.

van Eeden, D.G., Van Rensburg, B.J., De Wijn, M. and du P. Bothma, J. (2019). The value of community-based conservation in a heterogeneous landscape: a case study from the Maputaland centre of plant endemism, South Africa. In: *Conservation without boundaries: Case Studies from the Lubombo TFCA.* Kloppers, R.J. (ed.). pp. 41-55.

Published Conference Proceedings and Abstracts

Brundu, G., Pauchard, A., Pyšek, P. and Richardson, D.M. (2019). (Towards) a global strategy for invasive alien trees. In: *15th EMAPI International Conference.* Prague, Czech Republic. *Presquisa Florestal Brasileira.* **39,** pp. 559-560.

Herrel, A., Fabre, A.C., Zablocki-Thomas, P., Boistel, R., Measey, G.J., Dollion, A.Y., Luger, A.M., Adriaens, D., Anderson, C.V. and Tolley, K.A. (2019). Manual and Tail Prehensile Systems in Vertebrates: Performance and Morphology. *Journal of Morphology* **280,** pp. S44-S45.

Peer-reviewed Journal Articles

Abrahams, B., Sitas, N. and Esler, K.J. (2019). Exploring integrative research in the context of invasive alien plant management. *South African Journal of Science* **115**, #4263, 11 pages. DOI: 10.17159/sajs.2019/4263

Abrahams, B., Sitas, N. and Esler, K.J. (2019). Exploring the dynamics of research collaborations by mapping social networks in invasion science. *Journal of Environmental Management* **229**, 27-37.

Allen, B.L., Allen, L.R., Ballard, G., Drouilly, M., Fleming, P.J.S., Hampton, J.O., Hayward, M.W., Kerley, G.I.H., Meek, P.D., Minnie, L., O'Riain, M.J., Parker, D.M. and Somers, M.J. (2019). Animal welfare considerations for using large carnivores and guardian dogs as vertebrate biocontrol tools against other animals. *Biological Conservation* **232**, 258-270.

Allen, B.L., Allen, L.R., Ballard, G., Drouilly, M., Fleming, P.J.S., Hampton, J.O., Hayward, M.W., Kerley, G.I.H., Meek, P.D., Minnie, L., O'Riain, M.J., Parker, D.M. and Somers, M.J. (2019). Bringing objectivity to wildlife management: welfare effects of guardian dogs. *Biological Conservation* **236**, 582.

Allsopp, N., Slingsby, J.A. and Esler, K.J. (2019). Identifying research questions for the conservation of the Cape Floristic Region. *South African Journal of Science* **115**, 5889, 8 pages. DOI: 10.17159/sajs.2019/5889.

Ansong, M., Pergl, J., Essl, F., Hejda, M., van Kleunen, M., Randall, R. and Pyšek, P. (2019). Naturalized and invasive alien flora of Ghana. *Biological Invasions* **21**, 669-683.

Araújo, M.B., Anderson, R.P., Barbosa, A.M., Beale, C.M., Dormann, C.F., Early, R., Garcia, R.A., Guisan, A., Maiorano, L., Naimi, B., O'Hara, R.B., Zimmermann, N.E. and Rahbek, C. (2019). Standards for distribution models in biodiversity assessments. *Science Advances* **5**, eaat4858, 10 pages. DOI: 10.1126/sciadv.aat4858.

Balbi, S., Selomane, O., Sitas, N., Blanchard, R., Kotzee, I., O'Farrell, P. and Villa, F. (2019). Human dependence on natural resources in rapidly urbanising South African regions. *Environmental Research Letters* **14**, 044008, 12 pages. DOI: 10.1088/1748-9326/aafe43.

Baltzinger, C., Karimi, S. and Shukla, U. (2019). Plants on the move: Hitch-hiking with ungulates distributes diaspores across landscapes. *Frontiers in Ecology and Evolution* **7**, 38, 19 pages. DOI: 10.3389/fevo.2019.00038.

Barton, M.G., Clusella-Trullas, S. and Terblanche, J.S. (2019). Spatial scale, topography and thermoregulatory behaviour interact when modelling species' thermal niches. *Ecography* **42**, 376-389.

Barton, M.G., Terblanche, J.S. and Sinclair, B.J. (2019). Incorporating temperature and precipitation extremes into process-based models of African Lepidoptera changes the predicted distribution under climate change. *Ecological Modelling* **394**, 53-65.

Baxter-Gilbert, J. and Riley, J.L. (2019). Leopard tortoise (*Stigmochelys pardalis*) road mortality and extralimital occurrence in Western Cape, South Africa. *Biodiversity Observations* **10**, 12, 4 pages. DOI: 10.15641/bo.v10i0.732.

Bellingan, T.A., Hugo, S., Woodford, D.J., Gouws, J., Villet, M.H. and Weyl, O.L.F. (2019). Rapid recovery of macroinvertebrates in a South African stream treated with rotenone. *Hydrobiologia* **834**, 1-11.

Bentley, L.K., Robertson, M.P. and Barker, N.P. (2019). Range contraction to a higher elevation: the likely future of the montane vegetation in South Africa and Lesotho. *Biodiversity and Conservation* **28**, 131-153.

Bishop, T.R., Parr, C.L., Gibb, H., van Rensburg, B.J., Braschler, B., Chown, S.L., Foord, S.H., Lamy, K., Munyai, T.C., Okey, I., Tshivhandekano, P.G., Werenkraut, V. and Robertson, M.P. (2019). Thermoregulatory traits combine with range shifts to alter the future of montane ant assemblages. *Global Change Biology* **25**, 2162-2173.

Blackburn, T.M., Bellard, C. and Ricciardi, A. (2019). Alien versus native species as drivers of recent extinctions. *Frontiers in Ecology and Evolution* **17**, 203-207.

Boersma, N., Boardman, L., Gilbert, M. and Terblanche, J.S. (2019). Cold treatment enhances low-temperature flight performance in false codling moth, *Thaumatotibia leucotreta* (Lepidoptera: Tortricidae) *Agricultural and Forest Entomology* **21**, 243-251.

Bortolus, A., Adam, P*., et al.* (2019). Supporting *Spartina*: Interdisciplinary perspective shows *Spartina* as a distinct solid genus *Ecology* **100**, e02863, 6 pages. DOI: 10.1002/ecy.2863.

Bosc, C., Hui, C., Roets, F. and Pauw, A. (2019). Importance of biotic niches versus drift in a plant-inhabiting arthropod community depends on rarity and trophic group. *Ecography* **42**, 1926-1935.

Bradley, B.A., Laginhas, B.B., Whitlock, R., Allen, J.M., Bates, A.E., Bernatchez, G., Diez, J.M., Early, R., Lenoir, J., Vilà, M. and Sorte, C.J.B. (2019). Disentangling the abundance–impact relationship for invasive species. *Proceedings of the National Academy of Sciences of the United States of America* **116**, 9919-9924.

Buccellato, L., Byrne, M.J., Fisher, J.T. and Witkowski, E.T.F. (2019). Post-release evaluation of a combination of biocontrol agents on Crofton weed: testing extrapolation of greenhouse results to field conditions. *Biocontrol* **64**, 457-468.

Bunney, K., Robertson, M. and Bond, W. (2019). The historical distribution of megaherbivores does not determine the distribution of megafaunal fruit in southern Africa. *Biological Journal of the Linnean Society* **128**, 1039-1051.

Canavan, S., Kumschick, S., Le Roux, J.J., Richardson, D.M. and Wilson, J.R.U. (2019). Does origin determine environmental impacts? Not for bamboos. *Plants People Planet* **1**, 119-128.

Canavan, S., Meyerson, L.A., Packer, J.G., Pyšek, P., Maurel, N., Lozano, V., Richardson, D.M., Brundu, G., Canavan, K., Cicatelli, A., Čuda, J., Dawson, W., Essl, F., Guarino, F., Guo, W.-Y., van Kleunen, M., Kreft, H., Lambertini, C., Pergl, J., Skálová, H., Soreng, R.J., Visser, V., Vorontsova, M.S., Weigelt, P., Winter, M. and Wilson, J.R.U. (2019). Tall-statured grasses: a useful functional group for invasion science. *Biological Invasions* **21**, 37-58.

Canavan, S., Richardson, D.M., Le Roux, J.J. and Wilson, J.R.U. (2019). Alien bamboos in South Africa: a socio-historical perspective. *Human Ecology* **47**, 121-133.

Carruthers, J. and Foxcroft, L.C. (2019). *Koedoe*: *African Protected Area Conservation and Science* – A retrospection: 1958 to 2018. *Koedoe* **61**, a1556, 6 pages. DOI: 10.4102/koedoe.v61i1.1556.

Castro-Diez, P., Vaz, A.S*., et al.* (2029). Global effects of non-native tree species on multiple ecosystem services. *Biological Reviews* **94**, 1477-1501.

Cheney, C., Esler, K.J., Foxcroft, L.C. and van Wilgen, N.J. (2019). Scenarios for the management of invasive *Acacia* species in a protected area: implications of clearing efficacy. *Journal of Environmental Management* **238**, 274-282.

Conradie, S.R., Hall, G., Somers, M.J. and McIntyre, T. (2019). Limited animal-facilitated nutrient transfer across an aquatic–terrestrial interface in a southern African savanna. *African Journal of Wildlife Research* **49**, 52-61.

Cowie, B.W., Strathie, L.W., Goodall, J.M., Venter, N., Witkowski, E.T.F. and Byrne, M.J. (2019). Does host plant quality constrain the performance of the Parthenium beetle *Zygogramma bicolorata*? *Biological Control* **139**, 104078, 8 pages. DOI: 10.1016/j.biocontrol.2019.104078.

Crous, C.J., Drake, D.C., Jacobsen, A.L., Pratt, R.B., Jacobs, S.M. and Esler, K.J. (2019). Foliar nitrogen dynamics of an invasive legume compared to native non-legumes in fynbos riparian zones varying in water availability. *Water SA* **45**, 103-109.

Dalerum, F., Retief, T.A., Havemann, C.P., Chimimba, C.T. and van Rensburg, B.J. (2019). The influence of distance to perennial surface water on ant communities in Mopane woodlands, northern Botswana. *Ecology and Evolution* **9**, 154-165.

Davies, S.J., Hill, M.P., McGeoch, M.A. and Clusella-Trullas, S. (2019). Niche shift and resource supplementation facilitate an amphibian range expansion. *Diversity and Distributions* **25**, 154-165.

De Araujo, L.I., Karsten, M. and Terblanche, J.S. (2019). Exploring thermal flight responses as predictors of flight ability and geographic range size in *Drosophila*. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology* **236**, 110532, 7 pages. DOI: 10.1016/j.cbpa.2019.110532.

Dean, W.R.J., Seymour, C.L., Joseph, G.S. and Foord, S.H. (2019). A review of the impacts of roads on wildlife in semi-arid regions. *Diversity* **11**, 81, 19 pages. DOI: 10.3390/d11050081.

Dippenaar-Schoeman, A.S. and Foord, S.H. (2019). New records of *Cladomelea* from South Africa, including the first records of *C. longipes* (O. Pickard-Cambridge, 1877) (Araneae, Araneidae) outside its type locality. *Check List* **15**, 1071-1075.

Duncan, R.P., Cassey, P., Pigot, A.L. and Blackburn, T.M. (2019). A general model for alien species richness. *Biological Invasions* **21**, 2665-2677.

Erasmus, J.H., Malherbe, W., Gerber, R., Weyl, O.L.F., Sures, B., Wepener, V. and Smit, N.J. (2019). First record of *Labeo capensis* (Smith, 1841) in the Crocodile River (West) system: another successful non-native freshwater fish introduction in South Africa. *African Journal of Aquatic Science* **44**, 177-181.

Essl, F., Dawson, W., Kreft, H., Pergl, J., Pyšek, P., Van Kleunen, M., Weigelt, P., Mang, T., Dullinger, S., Lenzner, B., Moser, D., Maurel, N., Seebens, H., Stein, A., Weber, E., Chatelain, C., Inderjit, Genovesi, P., Kartesz, J., Morozova, O., Nishino, M., Nowak, P., Pagad, S., Shu, W.-S. and Winter, M. (2019). Drivers of the relative richness of naturalized and invasive plant species on Earth. *AoB Plants* **11**, plz051, 13 pages. DOI: 10.1093/aobpla/plz051.

Essl, F., Dullinger, S., Genovesi, P., Hulme, P.E., Jeschke, J.M., Katsanevakis, S., Kühn, I., Lenzner, B., Pauchard, A., Pyšek, P., Rabitsch, W., Richardson, D.M., Seebens, H., van Kleunen, M., van der Putten, W.H., Vilà, M. and Bacher, S. (2019). A conceptual framework for range-expanding species that track human-induced environmental change. *BioScience* **69**, 908-919.

Fenesi, A., Sándor, D., Pyšek, P., Dawson, W., Ruprecht, E., Essl, F., Kreft, H., Pergl, J., Weigelt, P., Winter, M. and van Kleunen, M. (2019). The role of fruit heteromorphism in the naturalization of Asteraceae. *Annals of Botany* **123**, 1043-1052.

Fey, S.B., Vasseur, D.A., Alujević, K., Kroeker, K.J., Logan, M.L., O'Connor, M.I., Rudolf, V.H.W., DeLong, J.P., Peacor, S., Selden, R.L., Sih, A. and Clusella-Trullas, S. (2019). Opportunities for behavioral rescue under rapid environmental change. *Global Change Biology* **25**, 3110-3120.

Foden, W.B., Young, B.E., Akçakaya, H.R., Garcia, R.A., Hoffmann, A.A., Stein, B.A., Thomas, C.D., Wheatley, C.J., Bickford, D., Carr, J.A., Hole, D.G., Martin, T.G., Pacifici, M., Pearce-Higgins, J.W., Platts, P.J., Visconti, P., Watson, J.E.M. and Huntley, B. (2019). Climate change vulnerability assessment of species. *WIREs Climate Change*, e551, 36 pages. DOI: 10.1002/wcc.551.

Foord, S., Dippenaar-Schoeman, A.S., Haddad, C.R., Schoeman, C., Hahn, N. and Lyle, R. (2019). Spider checklist for the Blouberg, in the Vhembe Biosphere Reserve, South Africa. *Bothalia* **49**, a2455, 13 pages. DOI: 10.4102/abc.v49i1.2455.

Foster, J.D., Ellis, A.G., Foxcroft, L.C., Carroll, S.P. and Le Roux, J.J. (2019). The potential evolutionary impact of invasive balloon vines on native soapberry bugs in South Africa. *NeoBiota* **49**, 19-35.

Foxcroft, L.C., Spear, D., van Wilgen, N.J. and McGeoch, M.A. (2019). Assessing the association between pathways of alien plant invaders and their impacts in protected areas. *NeoBiota* **43**, 1-25.

Frost, C.M., Allen, W.J., Courchamp, F., Jeschke, J.M., Saul, W.C. and Wardle, D.A. (2019). Using network theory to understand and predict biological invasions. *Trends in Ecology & Evolution* **34**, 831-843.

Gallien, L., Thornhill, A.H., Zurell, D., Miller, J.T. and Richardson, D.M. (2019). Global predictors of alien plant establishment success: combining niche and trait proxies. *Proceedings of the Royal Society B-Biological Sciences* **286**, 20182477, 8 pages. DOI: 10.1098/rspb.2018.2477.

Garcia, R.A., Allen, J.L. and Clusella-Trullas, S. (2019). Rethinking the scale and formulation of indices assessing organism vulnerability to warmer habitats. *Ecography* **42**, 1024-1036.

Garcia, R.A. and Clusella-Trullas, S. (2019). Thermal landscape change as a driver of ectotherm responses to plant invasions. *Proceedings of the Royal Society B-Biological Sciences* **286**, 20191020, 9 pages. DOI: 10.1098/rspb.2019.1020.

Gaudard, C.A., Robertson, M.P. and Bishop, T.R. (2019). Low levels of intraspecific trait variation in a keystone invertebrate group. *Oecologia* **190**, 725-735.

Giliomee, J.H. and Millar, I.M. (2019). An assessment of the Seychelles scale *Icerya seychellarum* (Westwood) as a potential insect of economic importance in South Africa. *African Entomology* **27**, 258-260.

Gioria, M., Le Roux, J.J., Hirsch, H., Moravcová, L. and Pyšek, P. (2019). Characteristics of the soil seed bank of invasive and non-invasive plants in their native and alien distribution range. *Biological Invasions* **21**, 2313-2332.

Groom, Q., Desmet, P., Reyserhove, L., Adriaens, T., Oldoni, D., Vanderhoeven, S., Baskauf, S.J., Chapman, A., McGeoch, M., Walls, R., Wieczorek, J., Wilson, J.R.U., Zermoglio, P.F.F. and Simpson, A. (2019). Improving Darwin Core for research and management of alien species. *Biodiversity Information Science and Standards* **3**, e38084, 24 pages. DOI: 10.3897/biss.3.38084

Gumede, S.T. and Downs, C.T. (2019). Sugar preference of invasive common mynas (*Sturnus tristis*). *Journal of Ornithology* **160**, 71-78.

Haddad, C.R., de Jager, L.J.C. and Foord, S.H. (2019). Habitats and cardinal directions are key variables structuring spider leaf litter assemblages under *Searsia lancea*. *Pedobiologia* **73**, 10-19.

Hargrove, J.S., Weyl, O.L.F., Zhao, H., Peatman, E. and Austin, J.D. (2019). Using species-diagnostic SNPs to detail the distribution and dynamics of hybridized black bass populations in southern Africa. *Biological Invasions* **21**, 1499-1509.

Hayward, M.W. (2019). The importance of experimentation in translocation research. *Animal Conservation* **22**, 120-121.

Hayward, M.W., Callen, A.*, et al.* (2019). Deconstructing compassionate conservation. *Conservation Biology* **33**, 760-768.

Hayward, M.W., Jachowski, D.S., Bugir, C.K., Clulow, J., Krishnamurthy, R., Griffin, A.S., Chalmers, A.C., Linnell, J.D.C., Montgomery, R.A., Somers, M.J., Kowalczyk, R., Heurich, M., Caravaggi, A., Marnewick, K.A., Di Blanco, Y., Shuttleworth, C.M., Callen, A., Weise, F., Scanlon, R., Moehrenschlager, A., Howell, L.G. and Upton, R.M.O. (2019). The search for novelty continues for rewilding. *Biological Conservation* **236**, 584-585.

Hayward, M.W., Scanlon, R.J.*, et al.* (2019). Reintroducing rewilding to restoration – Rejecting the search for novelty. *Biological Conservation* **233**, 255-259.

Heger, T., Bernard-Verdier, M., Gessler, A., Greenwood, A.D., Grossart, H.-P., Hilker, M., Keinath, S., Kowarik, I., Kueffer, C., Marquard, E., Müller, J., Niemeier, S., Onandia, G., Petermann, J.S., Rillig, M.C., Rödel, M.-O., Saul, W.-C., Schittko, C., Tockner, K., Joshi, J. and Jeschke, J.M. (2019). Towards an integrative, eco-evolutionary understanding of ecological novelty: studying and communicating interlinked effects of global change. *BioScience* **69**, 888-899.

Hirsch, H., Castillo, M.L., Impson, F.A.C., Kleinjan, C., Richardson, D.M. and Le Roux, J.J. (2019). Ghosts from the past: even comprehensive sampling of the native range may not be enough to unravel the introduction history of invasive species – the case of *Acacia dealbata* invasions in South Africa. *American Journal of Botany* **106**, 352-362.

Huang, W., Ratkowsky, D.A., Hui, C., Wang, P., Su, J. and Shi, P. (2019). Leaf fresh weight versus dry weight: which is better for describing the scaling relationship between leaf biomass and leaf area for broad-leaved plants. *Forests* **10**, 256, 19 pages. DOI: 10.3390/f10030256.

Hui, C. and Richardson, D.M. (2019). How to invade an ecological network. *Trends in Ecology & Evolution* **34**, 121-131.

Hui, C. and Richardson, D.M. (2019). Network invasion as an open dynamical system: response to Rossberg and Barabás. *Trends in Ecology & Evolution* **34**, 386-387.

Hulbert, J.M., Turner, S.C. and Scott, S.L. (2019). Challenges and solutions to establishing and sustaining citizen science projects in South Africa. *South African Journal of Science* **115**, #5844, 4 pages. DOI: 10.17159/sajs.2019/5844.

Jami, F., Marincowitz, S., Slippers, B., Crous, P.W., Le Roux, J.J., Richardson, D.M. and Wingfield, M.J. (2019). *Botryosphaeriaceae* associated with *Acacia heterophylla* (La Réunion) and *Acacia koa* (Hawaii). *Fungal Biology* **123**, 783-790.

Javal, M., Lombaert, E., Tsykun, T., Courtin, C., Kerdelhué, C., Prospero, S., Roques, A. and Roux, G. (2019). Deciphering the worldwide invasion of the Asian long-horned beetle: a recurrent

invasion process from the native area together with a bridgehead effect. *Molecular Ecology* **28**, 951-967.

Javal, M., Terblanche, J.S., Conlong, D.E. and Malan, A.P. (2019). First screening of entomopathogenic nematodes and fungus as biocontrol agents against an emerging pest of sugarcane, *Cacosceles newmannii* (Coleoptera: Cerambycidae) *Insects* **10**, 117, 11 pages. DOI: 10.3390/insects10040117.

Javal, M., Thomas, S., Lehmann, P., Barton, M.G., Conlong, D.E., Du Plessis, A. and Terblanche, J.S. (2019). The effect of oxygen limitation on a xylophagous insect's heat tolerance is influenced by life-stage through variation in aerobic scope and respiratory anatomy. *Frontiers in Physiology* **10**, 1426, 11 pages. DOI: 10.3389/fphys.2019.01426.

Jordaan, R.K., Somers, M.J., Hall, G. and McIntyre, T. (2019). Plasticity and specialisation in the isotopic niche of African clawless otters foraging in marine and freshwater habitats. *Mammalian Biology* **98**, 61-72.

Joseph, G.S., Muluvhahothe, M.M., Seymour, C.L., Munyai, T.C., Bishop, T.R. and Foord, S.H. (2019). Stability of Afromontane ant diversity decreases across an elevation gradient. *Global Ecology and Conservation* **17**, e00596, 9 pages. DOI: 10.1016/j.gecco.2019.e00596.

Kamutando, C.N., Vikram, S., Kamgan-Nkuekam, G., Makhalanyane, T.P., Greve, M., Le Roux, J.J., Richardson, D.M., Cowan, D.A. and Valverde, A. (2019). The functional potential of the rhizospheric microbiome of an invasive tree species, *Acacia dealbata*. *Microbial Ecology* **77**, 191-200.

Karsten, M., Lebenzon, J.E., Sinclair, B.J. and Terblanche, J.S. (2019). Loss of ion homeostasis is not the cause of chill coma or impaired dispersal in false codling moth *Thaumatotibia leucotreta* (Lepidoptera: Tortricidae). *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology* **229**, 40-44.

Katembo, N., Witkowski, E.T.F. and Byrne, M.J. (2019). Effects of Carbofuran on *Lantana camara* and its biocontrol agent, *Teleonemia scrupulosa*. *Biocontrol Science and Technology* **29**, 746-756.

Keet, J.H., Ellis, A.G., Hui, C. and Le Roux, J.J. (2019). Strong spatial and temporal turnover of soil bacterial communities in South Africa's hyperdiverse fynbos biome. *Soil Biology and Biochemistry* **136**, 107541, 12 pages. DOI: 10.1016/j.soilbio.2019.107541.

Kerley, G.I.H., Behrens, K.G., Carruthers, J., Diemont, M., du Plessis, J., Minnie, L., Somers, M.J., Tambling, C.J., Turpie, J., Wilson, S. and Balfour, D. (2019). Building assessment practice and lessons from the scientific assessment on livestock predation in South Africa. *South African Journal of Science* **115**, 18-21.

Khosa, D., Marr, S.M., Wasserman, R.J., Zengeya, T.A. and Weyl, O.L.F. (2019). An evaluation of the current extent and potential spread of Black Bass invasions in South Africa. *Biological Invasions* **21**, 1721-1736.

Kotze, D.C., Tererai, F. and Grundling, P.-L. (2019). Assessing, with limited resources, the ecological outcomes of wetland restoration: a South African case. *Restoration Ecology* **27**, 495-503.

Koutika, L.-S. and Richardson, D.M. (2019). *Acacia mangium* Willd: benefits and threats associated with its increasing use around the world. *Forest Ecosystems* **6**, 2, 13 pages. DOI: 10.1186/s40663-019-0159-1.

Kovacevic, A., Latombe, G. and Chown, S.L. (2019). Rate dynamics of ectotherm responses to thermal stress. *Proceedings of the Royal Society B-Biological Sciences* **286**, 20190174, 9 pages. DOI: 10.1098/rspb.2019.0174.

Král, J., Forman, M., Kořínková, T., Lerma, A.C.R., Haddad, C.R., Musilová, J., Řezáč, M., Herrera, I.M.A., Thakur, S., Dippenaar-Schoeman, A.S., Marec, F., Horová, L. and Bureš, P. (2019). Insights into the karyotype and genome evolution of haplogyne spiders indicate a plyploid origin of lineage with holokinetic chromosomes. *Scientific Reports* **9**, #3001, 14 pages.

Kruger, N., Measey, J., Herrel, A. and Secondi, J. (2019). Anti-predator strategies of the invasive African clawed frog, *Xenopus laevis*, to native and invasive predators in western France. *Aquatic Invasions* **14**, 433-443.

Latombe, G., Canavan, S., Hirsch, H., Hui, C., Kumschick, S., Nsikani, M.N., Potgieter, L.J., Robinson, T.B., Saul, W.-C., Turner, S.C., Wilson, J.R.U., Yannelli, F.A. and Richardson, D.M. (2019). A four-component classification of uncertainties in biological invasions: implications for management. *Ecosphere* **10**, e02669, 25 pages. DOI: 10.1002/ecs2.2669.

Latombe, G., Roura-Pascual, N. and Hui, C. (2019). Similar compositional turnover but distinct insular environmental and geographical drivers of native and exotic ants in two oceans. *Journal of Biogeography* **46**, 2299-2310.

Le Maitre, D., Gorgens, A., Howard, G. and Walker, N. (2019). Impacts of alien plant invasions on water resources and yields from the Western Cape Water Supply System (WCWSS). *Water SA* **45**, 568-579.

Le Roux, J.J., Hui, C., Castillo, M.L., Iriondo, J.M., Keet, J.-H., Khapugin, A.A., Médail, F., Rejmánek, M., Theron, G., Yannelli, F.A. and Hirsch, H. (2019). Recent anthropogenic plant extinctions differ in biodiversity hotspots and coldspots. *Current Biology* **29**, 2912-2918.

Lehmann, P., Javal, M. and Terblanche, J.S. (2019). Oxygen limitation is not the cause of death during lethal heat exposure in an insect. *Biology Letters* **15**, 20180701, 4 pages. DOI: 10.1098/rsbl.2018.0701.

Linden, V.M.G., Grass, I., Joubert, E., Tscharntke, T., Weier, S.M. and Taylor, P.J. (2019). Ecosystem services and disservices by birds, bats and monkeys change with macadamia landscape heterogeneity. *Journal of Applied Ecology* **56**, 2069-2078.

Liu, X., Blackburn, T.M., Song, T., Li, X., Huang, C. and Li, Y. (2019). Risks of biological invasion on the belt and road. *Current Biology* **29**, 499-505.

Logan, M.L., van Berkel, J. and Clusella-Trullas, S. (2019). The Bogert Effect and environmental heterogeneity. *Oecologia* **191**, 817-827.

Loureiro, T.G., Anastacio, P.M., Bueno, S.L.D., Wood, C.T. and Araujo, P.B. (2019). Food matters: Trophodynamics and the role of diet in the invasion success of *Procambarus clarkii* in an Atlantic Forest conservation area. *Limnologica* **79**, 125717, 15 pages. DOI: 10.1016/j.limno.2019.125717.

MacFadyen, S., Hui, C., Verburg, P.H. and van Teeffelen, A.J.A. (2019). Spatiotemporal distribution dynamics of elephants in response to density, rainfall, rivers and fire in Kruger National Park, South Africa. *Diversity and Distributions* **25**, 880-894.

Magadzire, N., de Klerk, H.M., Esler, K.J. and Slingsby, J.A. (2019). Fire and life history affect the distribution of plant species in a biodiversity hotspot. *Diversity and Distributions* **25**, 1012-1023.

Mangachena, J.R. and Geerts, S. (2019). The absence of keystone indigenous trees inhibits bird recovery up to a decade after invasive tree removal from riparian habitats. *Acta Oecologica* **101**, 103483, 10 pages. DOI: 10.1016/j.actao.2019.103483.

Mannetti, L.M., Gottert, T., Zeller, U. and Esler, K.J. (2019). Identifying and categorizing stakeholders for protected area expansion around a national park in Namibia. *Ecology and Society* **24**, #5, 21 pages. DOI: 10.5751/ES-10790-240205.

Marlin, D., Smit, E.R. and Byrne, M.J. (2019). A successful biocontrol agent in the USA, *Diorhabda carinulata* (Coleoptera: Chrysomelidae) on *Tamarix* spp. (Tamaricaceae), rejected in South Africa due to insufficient host specificity. *Biological Control* **136**, 104002, 7 pages. DOI: 10.1016/j.biocontrol.2019.104002.

Marneweck, C., Becker, P., Beverley, G., Davies-Mostert, H., du Plessis, C., Forssman, K., Graf, J., Gusset, M., Hofmeyr, M., Kelly, C., Kilian, P., Marchal, A., Marneweck, D., Marnewick, K., Owen, C., Postiglione, G., Slotow, R., Somers, M., Gunther, M., van Dyk, G., Whittington-

Jones, B. and Parker, D. (2019). Factors affecting the success of artificial pack formation in an endangered, social carnivore: the African wild dog. *Animal Conservation* **22**, 493-502.

Marneweck, D.G., Druce, D.J. and Somers, M.J. (2019). Food, family and female age affect reproduction and pup survival of African wild dogs. *Behavioral Ecology and Sociobiology* **73**, 65, 15 pages. DOI: 10.1007/s00265-019-2676-x.

Mayonde, S., Cron, G.V., Glennon, K.L. and Byrne, M.J. (2019). Genetic diversity assessment of *Tamarix* in South Africa – biocontrol and conservation implications. *South African Journal of Botany* **121**, 54-62.

McGeoch, M.A., Latombe, G., Andrew, N.R., Nakagawa, S., Nipperess, D.A., Roigé, M., Marzinelli, E.M., Campbell, A.H., Vergés, A., Thomas, T., Steinberg, P.D., Selwood, K.E., Henriksen, M.V. and Hui, C. (2019). Measuring continuous compositional change using decline and decay in zeta diversity. *Ecology* **100**, e02832. DOI: 10.1002/ecy.2832.

Measey, J., Basson, A., Rebelo, A.D., Nunes, A.L., Vimercati, G., Louw, M. and Mohanty, N.P. (2019). Why have a pet amphibian? Insights from YouTube. *Frontiers in Ecology and Evolution* **7**, 52, 8 pages. DOI: 10.3389/fevo.2019.00052.

Measey, J., Tarrant, J., Rebelo, A., Turner, A., du Preez, L., Mokhatla, M. and Conradie, W. (2019). Has strategic planning made a difference to amphibian conservation research in South Africa? *Bothalia* **49**, a2428, 13 pages. DOI: 10.4102/abc.v49i1.2428.

Measey, J., Visser, V., Dgebuadze, Y., Inderjit, Li, B., Dechoum, M., Ziller, S.R. and Richardson, D.M. (2019). The world needs BRICS countries to build capacity in invasion science. *PLoS Biology* **17**, e3000404, 7 pages. DOI: 10.1371/journal.pbio.3000404.

Milotić, T., Baltzinger, C*., et al.* (2019). Functionally richer communities improve ecosystem functioning: dung removal and secondary seed dispersal by dung beetles in the Western Palaearctic. *Journal of Biogeography* **46**, 70-82.

Mkhize, N.L. and Olkers, T. (2019). Persistence of the flowerbud weevil *Anthonomus santacruzi* in optimal versus marginal areas: implications for the biological control of the invasive tree *Solanum mauritianum* in South Africa. *Biocontrol Science and Technology* **29**, 649-660.

Mofu, L., Cuthbert, R.N., Dalu, T., Woodford, D.J., Wasserman, R.J., Dick, J.T.A. and Weyl, O.L.F. (2019). Impacts of non-native fishes under a seasonal temperature gradient are forecasted using functional responses and abundances. *NeoBiota* **49**, 57-75.

Mofu, L., South, J., Wasserman, R.J., Dalu, T., Woodford, D.J., Dick, J.T.A. and Weyl, O.L.F. (2019). Inter-specific differences in invader and native fish functional responses illustrate neutral effects on prey but superior invader competitive ability. *Freshwater Biology* **64**, 1655-1663.

Mofu, L., Woodford, D.J., Wasserman, R.J., Dalu, T. and Weyl, O.L.F. (2019). Diet of *Glossogobius callidus* (Teleostei: Gobiidae) in freshwater impoundments in the Sundays River Valley of the Eastern Cape, South Africa. *African Journal of Aquatic Science* **44**, 415-420.

Mohanty, N.P. and Measey, J. (2019). The global pet trade in amphibians: species traits, taxonomic bias, and future directions. *Biodiversity and Conservation* **28**, 3915-3923.

Mohanty, N.P. and Measey, J. (2019). No survival of native larval frogs in the presence of invasive Indian bullfrog *Hoplobatrachus tigerinus* tadpoles. *Biological Invasions* **21**, 2281-2286.

Mohanty, N.P. and Measey, J. (2019). Reconstructing biological invasions using public surveys: a new approach to retrospectively assess spatio-temporal changes in invasive spread. *Biological Invasions* **21**, 467-480.

Mokhatla, M., Measey, J. and Smit, B. (2019). The role of ambient temperature and body mass on body temperature, standard metabolic rate and evaporative water loss in southern African anurans of different habitat specialisation. *PeerJ* **7**, e7885, 21 pages. DOI: 10.7717/peerj.7885.

Moreira, F., Allsopp, N., Esler, K.J., Wardell-Johnson, G., Ancillotto, L., Arianoutsou, M., Clary, J., Brotons, L., Clavero, M., Dimitrakopoulos, P.G., Fagoaga, R., Fiedler, P., Filipe, A.F.,

Frankenberg, E., Holmgren, M., Marquet, P.A., Martinez-Harms, M.J., Martinoli, A., Miller, B.P., Olsvig-Whittaker, L., Pliscoff, P., Rundel, P., Russo, D., Slingsby, J.A., Thompson, J., Wardell-Johnson, A. and Beja, P. (2019). Priority questions for biodiversity conservation in the Mediterranean biome: Heterogeneous perspectives across continents and stakeholders. *Conservation Science and Practice* **1**, e118, 11 pages. DOI: 10.1111/csp2.118.

Moshobane, M.C., Mukundamago, M., Adu-Acheampong, S. and Shackleton, R. (2019). Development of alien and invasive taxa lists for regulation of biological invasions in South Africa. *Bothalia* **49**, a2361, 11 pages. DOI: 10.4102/abc.v49i1.2361.

Mukarugwiro, J.A., Newete, S.W., Adam, E., Nsanganwimana, F., Abutaleb, K.A. and Byrne, M.J. (2019). Mapping distribution of water hyacinth (*Eichhornia crassipes*) in Rwanda using multispectral remote sensing imagery. *African Journal of Aquatic Science* **44**, 339-348.

Mungi, N.A., Kaushik, M., Mohanty, N.P., Rastogi, R., Johnson, J.A. and Qureshi, Q. (2019). Identifying knowledge gaps in the research and management of invasive species in India. *Biologia* **74**, 623-629.

Nengovhela, A., Braga, J., Denys, C., de Beer, F., Tenailleau, C. and Taylor, P.J. (2019). Associated tympanic bullar and cochlear hypertrophy define adaptations to true deserts in African gerbils and laminate-toothed rats (Muridae: Gerbillinae and Murinae). *Journal of Anatomy* **234**, 179-192.

Newete, S.W., Mayonde, S. and Byrne, M.J. (2019). Distribution and abundance of invasive *Tamarix* genotypes in South Africa. *Weed Research* **59**, 191-200.

Nnakenyi, C.A., Traveset, A., Heleno, R., Minoarivelo, H.O. and Hui, C. (2019). Fine-tuning the nested structure of pollination networks by adaptive interaction switching, biogeography and sampling effect in the Galápagos Islands. *Oikos* **128**, 1413-1423.

Novoa, A., Brundu, G., Day, M.D., Deltoro, V., Essl, F., Foxcroft, L.C., Fried, G., Kaplan, H., Kumschick, S., Lloyd, S., Marchante, E., Marchante, H., Paterson, I.D., Pyšek, P., Richardson, D.M., Witt, A., Zimmermann, H.G. and Wilson, J.R.U. (2019). Global actions for managing cactus invasions. *Plants* **8**, 421, 27 pages. DOI: 10.3390/plants8100421.

Novoa, A., Flepu, V. and Boatwright, J.S. (2019). Is spinelessness a stable character in cactus pear cultivars? Implications for invasiveness. *Journal of Arid Environments* **160**, 11-16.

Nsikani, M.M., Gaertner, M., Kritzinger-Klopper, S., Ngubane, N.P. and Esler, K.J. (2019). Secondary invasion after clearing invasive *Acacia saligna* in the South African fynbos. *South African Journal of Botany* **125**, 280-289.

Nunes, A.L., Fill, J.M., Davies, S.J., Louw, M., Rebelo, A.D., Thorp, C.J., Vimercati, G. and Measey, J. (2019). A global meta-analysis of the ecological impacts of alien species on native amphibians. *Proceedings of the Royal Society B-Biological Sciences* **286**, 20182528, 10 pages. DOI: 10.1098/rspb.2018.2528.

Ogden, N.H., Wilson, J.R.U., Richardson, D.M., Hui, C., Davies, S.J., Kumschick, S., Le Roux, J.J., Measey, J., Saul, W.-C. and Pulliam, J.R.C. (2019). Emerging infectious diseases and biological invasions: a call for a One Health collaboration in science and management. *Royal Society Open Science* **6**, #181577, 15 pages.

Padayachee, A.L., Procheş, S. and Wilson, J.R.U. (2019). Prioritising potential incursions for contingency planning: pathways, species, and sites in Durban (eThekwini), South Africa as an example. *NeoBiota* **47**, 31959, 21 pages. DOI: 10.3897/neobiota.47.31959

Panter, B. and Ruwanza, S. (2019). Spekboom (*Portulacaria afra*) planting in degraded thickets improves soil properties and vegetation diversity. *Ecological Restoration* **37**, 76-80.

Paterson, J.E., Baxter-Gilbert, J., Beaudry, F., Carstairs, S., Chow-Fraser, P., Edge, C.B., Lentini, A.M., Litzgus, J.D., Markle, C.E., McKeown, K., Moore, J.A., Refsnider, J.M., Riley, J.L., Rouse, J.D., Seburn, D.C., Zimmerling, J.R. and Davy, C.M. (2019). Road avoidance and its energetic consequences for reptiles. *Ecology and Evolution* **9**, 9794-9803.

Peters, K., Sink, K. and Robinson, T.B. (2019). Aliens cruising in: explaining alien fouling macro-invertebrate species numbers on recreational yachts. *Ocean & Coastal Management* **182**, 104986, 8 pages. DOI: 10.1016/j.ocecoaman.2019.104986.

Peters, K., Sink, K.J. and Robinson, T.B. (2019). Sampling methods and approaches to inform standardized detection of marine alien fouling species on recreational vessels. *Journal of Environmental Management* **230**, 159-167.

Pfaff, M.C., Logston, R.C*., et al.* (2019). A synthesis of three decades of socio-ecological change in False Bay, South Africa: setting the scene for multidisciplinary research and management. *Elementa-Science of the Anthropocene* **7**, 32, 49 pages. DOI: 10.1525/elementa.367.

Plasman, M., McCue, M.D., Reynoso, V.H., Terblanche, J.S. and Clusella-Trullas, S. (2019). Environmental temperature alters the overall digestive energetics and differentially affects dietary protein and lipid use in a lizard. *Journal of Experimental Biology* **222**, jeb194480, 9 pages. DOI: 10.1242/jeb.194480.

Potgieter, L.J., Gaertner, M., O'Farrell, P. and Richardson, D.M. (2019). Does vegetation structure influence criminal activity? Insights from Cape Town, South Africa. *Frontiers of Biogeography* **11**, e42035, 15 pages. DOI: 10.21425/F5FBG42035.

Potgieter, L.J., Gaertner, M., O'Farrell, P.J. and Richardson, D.M. (2019). A fine-scale assessment of the ecosystem service-disservice dichotomy in the context of urban ecosystems affected by alien plant invasions. *Forest Ecosystems* **6**, 46, 16 pages. DOI: 10.1186/s40663-019-0200-4

Potgieter, L.J., Gaertner, M., O'Farrell, P.J. and Richardson, D.M. (2019). Perceptions of impact: invasive alien plants in the urban environment. *Journal of Environmental Management* **229**, 76-87.

Purdon, J., Parr, C.L. and Somers, M.J. (2019). Grazing by large savanna herbivores indirectly alters ant diversity and promotes resource monopolisation. *PeerJ* **7**, e6226, 21 pages. DOI: 10.7717/peerj.6226.

Pyšek, P., Brundu, G., Brock, J., Child, L. and Wade, M. (2019). Twenty-five years of conferences on the Ecology and Management of Alien Plant invasions: the history of EMAPi 1992–2017. *Biological Invasions* **21**, 725-742.

Ramahlo, M., Chimimba, C.T., Pirk, C. and Ganswindt, A. (2019). Non-invasive monitoring of adrenocortical activity in free-ranging Namaqua rock mice *Micaelamys namaquensis* from South Africa in response to anthropogenic land use and season. *Wildlife Biology* **2019**, #00544, 6 pages. DOI: 10.2981/wlb.00544.

Razanajatovo, M., van Kleunen, M., Kreft, H., Dawson, W., Essl, F., Pergl, J., Pyšek, P., Winter, M. and Weigelt, P. (2019). Autofertility and self-compatibility moderately benefit island colonization of plants. *Global Ecology and Biogeography* **28**, 341-352.

Rebelo, A., Morris, C., Meire, P. and Esler, K.J. (2019). Ecosystem services provided by South African palmiet wetlands: a case for investment in strategic water source areas. *Ecological Indicators* **101**, 71-80.

Rebelo, A.D. and Measey, J. (2019). Locomotor performance constrained by morphology and habitat in a diverse clade of African frogs (Anura: Pyxicephalidae). *Biological Journal of the Linnean Society* **127**, 310-323.

Reizenberg, J.-L., Bloy, L.E., Weyl, O.L.F., Shelton, J.M. and Dallas, H.F. (2019). Variation in thermal tolerances of native freshwater fishes in South Africa's Cape Fold Ecoregion: examining the east-west gradient in species' sensitivity to climate warming. *Journal of Fish Biology* **94**, 103-112.

Rivers-Moore, N.A., Ellender, B.R. and Weyl, O.L.F. (2019). Modelling expected trout ranges under current and future water temperature regimes in the Eastern Cape, South Africa. *African Journal of Aquatic Science* **44**, 35-42.

Rossberg, A.G., Barabas, G., Possingham, H.P., Pascual, M., Marquet, P.A., Hui, C., Evans, M.R. and Meszena, G. (2019). Let's train more theoretical ecologists - here is why. *Trends in Ecology & Evolution* **34**, 759-762.

Roux, D.J., Kingsford, R.T., Cook, C.N., Carruthers, J., Dickson, K. and Hockings, M. (2019). The case for embedding researchers in conservation agencies. *Conservation Biology* **33**, 1266-1274.

Ruwanza, S. and Tshililo, K. (2019). Short term soil and vegetation recovery after *Acacia mearnsii* removal in Vhembe Biosphere Reserve, South Africa. *Applied Ecology and Environmental Research* **17**, 1705-1716.

Sadchatheeswara, S., Moloney, C.L., Branch, G.M. and Robinson, T.B. (2019). Blender interstitial volume: a novel virtual measurement of structural complexity applicable to marine benthic habitats. *MethodsX* **6**, 1728-1740.

Sadchatheeswaran, S., Moloney, C.L., Branch, G.M. and Robinson, T.B. (2019). Using empirical and simulation approaches to quantify merits of rival measures of structural complexity in marine habitats. *Marine Environmental Research* **149**, 157-169.

Schoeman, A.L., Kruger, N., Secondi, J. and du Preez, L.H. (2019). Repeated reduction in parasite diversity in invasive populations of *Xenopus laevis*: a global experiment in enemy release. *Biological Invasions* **21**, 1323-1338.

Shackleton, R.T., Adriaens, T., Brundu, G., Dehnen-Schmutz, K., Estévez, R.A., Fried, J., Larson, B.M.H., Liu, S., Marchante, H., Moshobane, M.C., Novoa, A., Reed, M. and Richardson, D.M. (2019). Stakeholder engagement in the study and management of invasive alien species. *Journal of Environmental Management* **229**, 88-101.

Shackleton, R.T., Larson, B.M.H., Novoa, A., Richardson, D.M. and Kull, C.A. (2019). The human and social dimensions of invasion science and management. *Journal of Environmental Management* **229**, 1-9.

Shackleton, R.T., Richardson, D.M., Shackleton, C.M., Bennett, B., Crowley, S.L., Dehnen-Schmutz, K., Estévez, R.A., Fischer, A., Kueffer, C., Kull, C.A., Marchante, E., Novoa, A., Potgieter, L.J., Vaas, J., Vaz, A.S. and Larson, B.M.H. (2019). Explaining people's perceptions of invasive alien species: a conceptual framework. *Journal of Environmental Management* **229**, 10-26.

Shackleton, R.T., Shackleton, C.M. and Kull, C.A. (2019). The role of invasive alien species in shaping local livelihoods and human well-being: a review. *Journal of Environmental Management* **229**, 145-157.

Shi, P.J., Zhao, L., Ratkowsky, D.A., Niklas, K.J., Huang, W.W., Lin, S.Y., Ding, Y.L., Hui, C. and Li, B.L. (2019). Influence of the physical dimension of leaf size measures on the goodness of fit for Taylor's power law using 101 bamboo taxa. *Global Ecology and Conservation* **19**, e00657, 7 pages. DOI: 10.1016/j.gecco.2019.e00657.

Simmonds, J.S., van Rensburg, B.J., Tulloch, A.I.T. and Maron, M. (2019). Landscape-specific thresholds in the relationship between species richness and natural land cover. *Journal of Applied Ecology* **56**, 1019-1029.

Sitas, N., Harmackova, Z.V.*, et al.* (2019). Exploring the usefulness of scenario archetypes in science-policy processes: experience across IPBES assessments. *Ecology and Society* **24**, 35, 25 pages. DOI: 10.5751/ES-11039-240335.

South, J., Botha, T.L., Wolmarans, N.J., Wepener, V. and Weyl, O.L.F. (2019). Assessing predator-prey interactions in a chemically altered aquatic environment: the effects of DDT on *Xenopus laevis* and *Culex* sp. larvae interactions and behaviour. *Ecotoxicology* **28**, 771-780.

South, J., McCard, M., Khosa, D., Mofu, L., Madzivanzira, T.C., Dick, J.T.A. and Weyl, O.L.F. (2019). The effect of prey identity and substrate type on the functional response of a globally invasive crayfish. *Neobiota* **52**, 9-24.

Steidinger, B.S., Crowther, T.W., Liang, J., Van Nuland, M.E., Werner, G.D.A., Reich, P.B., Nabuurs, G., de-Miguel, S., Zhou, M., Picard, N., Herault, B., Zhao, X., Zhang, C., Routh, D., GFBI-

Consortium and Peay, K.G. (2019). Climatic controls of decomposition drive the global biogeography of forest-tree symbioses. *Nature* **569**, 404-408.

Strydom, M., Veldtman, R., Ngwenya, M.Z. and Esler, K.J. (2019). Seed survival of Australian *Acacia* in the Western Cape of South Africa in the presence of biological control agents and given environmental variation. *PeerJ* **7**, e6816, 25 pages. DOI: 10.7717/peerj.6816.

Sunday, J., Bennett, J.M., Calosi, P., Clusella-Trullas, S., Gravel, S., Hargreaves, A.L., Leiva, F.P., Verberk, W.C.E.P., Olalla-Tárraga, M.A. and Morales-Castilla, I. (2019). Thermal tolerance patterns across latitude and elevation. *Philosophical Transactions of the Royal Society of B-Biological Sciences* **374**, 20190036. DOI: 10.1098/rstb.2019.0036.

Swart, C. and Robinson, T.B. (2019). Horizon scanning for alien predatory crabs: insights from South Africa. *African Journal of Marine Science* **41**, 125-135.

Taylor, G.C., Hill, J.M. and Weyl, O.L.F. (2019). The diet and trophic ecology of non-native *Micropterus salmoides* in two South African impoundments. *African Journal of Aquatic Science* **44**, 143-153.

Taylor, P.J., Denys, C. and Cotterill, F.P.D. (2019). Taxonomic anarchy or an inconvenient truth for conservation? Accelerated species discovery reveals evolutionary patterns and heightened extinction threat in Afro-Malagasy small mammals. *Mammalia* **83**, 313-329.

Taylor, P.J., MacDonald, A., Goodman, S.M., Kearney, T., Cotterill, F.P.D., Stoffberg, S., Monadjem, A., Schoeman, M.C., Guyton, J., Naskrecki, P., Engelbrecht, A. and Richards, L.R. (2019). CORRIGENDUM: Integrative taxonomy resolves three new cryptic species of small southern African horseshoe bats (*Rhinolophus*). *Zoological Journal of the Linnean Society* **187**, 535-537.

Telford, N.S., Channing, A. and Measey, J. (2019). Origin of invasive populations of the Guttural Toad (*Sclerophrys gutturalis*) on Reunion and Mauritius Islands and in Constantia, South Africa. *Herpetological Conservation and Biology* **14**, 380-392.

Thorp, C.J., Vonesh, J.R. and Measey, J. (2019). Cannibalism or congeneric predation? The African clawed frog, *Xenopus laevis* (Daudin), preferentially predates on larvae of Cape platannas, *Xenopus gilli* Rose & Hewitt. *African Journal of Ecology* **57**, 59-65.

Treasure, A.M. and Chown, S.L. (2019). Phenotypic plasticity in locomotor performance of a monophyletic group of weevils accords with the 'warmer is better' hypothesis. *Journal of Experimental Biology* **222**, jeb195255, 9 pages. DOI: 10.1242/jeb.195255.

Treasure, A.M., le Roux, P.C., Mashau, M.H. and Chown, S.L. (2019). Species-energy relationships of indigenous and invasive species may arise in different ways - a demonstration using springtails. *Scientific Reports* **9**, 13799, 12 pages. DOI: 10.1038/s41598-019-48871-1.

Tsykun, T., Javal, M., Hölling, D., Roux, G. and Prospero, S. (2019). Fine-scale invasion genetics of the quarantine pest, *Anoplophora glabripennis*, reconstructed in single outbreaks. *Scientific Reports* **9**, 19436, 10 pages. DOI: 10.1038/s41598-019-55698-3.

van der Walt, J.A., Marr, S.M., Wheeler, M.J., Impson, N.D., Garrow, C. and Weyl, O.L.F. (2019). Successful mechanical eradication of spotted bass (*Micropterus punctulatus* (Rafinesque, 1819)) from a South African river. *Aquatic Conservation: Marine and Freshwater Ecosystems* **29**, 303-311.

Venter, N., Mkasi, M., Mudau, P., Newete, S.W., Cowie, B.W., Witkowski, E.T.F. and Byrne, M.J. (2019). Differences between sun and shade habitats on the invasive shrub *Lantana camara* and its biocontrol agent *Teleonemia scrupulosa*. *Arthropod-Plant Interactions* **13**, 885-893.

Vermeulen, W., van Wilgen, N., Smith, K., Dopolo, M., Swemmer, L., Annecke, W., Bezuidenhout, H., Durrheim, G., Hanekom, N., Hendricks, H., McGeoch, M., Ngubeni, N. and Symonds, A. (2019). Monitoring consumptive resource use in South African national parks. *Koedoe* **61**, a1516, 11 pages. DOI: 10.4102/koedoe.v61i1.1516.

Vicente, J.R., Kueffer, C., Richardson, D.M., Vaz, A.S., Cabral, J.A., Hui, C., Araújo, M.B., Kühn, I., Kull, C.A., Verburg, P.H., Marchante, E. and Honrado, J.P. (2019). Different environmental drivers of alien tree invasion affect different life-stages and operate at different spatial scales. *Forest Ecology and Management* **433**, 263-275.

Vilizzi, L., Copp, G.H.*, et al.* (2019). A global review and meta-analysis of applications of the freshwater Fish Invasiveness Screening Kit. *Reviews in Fish Biology and Fisheries* **29**, 529-568.

Vimercati, G., Davies, S.J. and Measey, J. (2019). Invasive toads adopt marked capital breeding when introduced to a cooler, more seasonal environment *Biological Journal of the Linnean Society* **128**, 657-671.

Vogel, J.T., Somers, M.J. and Venter, J.A. (2019). Niche overlap and dietary resource partitioning in an African large carnivore guild. *Journal of Zoology* **309**, 212-223.

Wang, S., Hong, Y. and Measey, J. (2019). An established population of African clawed frogs, *Xenopus laevis* (Daudin, 1802), in mainland China. *BioInvasions Records* **8**, 457-464.

Warrington, S., Ellis, A., Novoa, A., Wandrag, E.M., Hulme, P.E., Duncan, R.P., Valentine, A. and Le Roux, J.J. (2019). Cointroductions of Australian acacias and their rhizobial mutualists in the Southern Hemisphere. *Journal of Biogeography* **46**, 1519-1531.

Weier, S.M., Moodley, Y., Fraser, M.F., Linden, V.M.G., Grass, I., Tscharntke, T. and Taylor, P.J. (2019). Insect pest consumption by bats in macadamia orchards established by molecular diet analyses. *Global Ecology and Conservation* **18**, e00626, 9 pages. DOI: 10.1016/j.gecco.2019.e00626.

Weise, F.J., Fynn, R.W.S., Stein, A.B., Tomeletso, M., Somers, M.J. and Périquet, S. (2019). Seasonal selection of key resources by cattle in a mixed savannah-wetland ecosystem increases the potential for conflict with lions. *Biological Conservation* **237**, 253-266.

Weise, F.J., Hauptmeier, H., Stratford, K.J., Hayward, M.W., Aal, K., Heuer, M., Tomeletso, M., Wulf, V., Somers, M.J. and Stein, A.B. (2019). Lions at the gates: trans-disciplinary design of an early warning system to improve human-lion coexistence. *Frontiers in Ecology and Evolution* **6**, 242, 19 pages. DOI: 10.3389/fevo.2018.00242.

Witt, A.B.R., Shackleton, R.T., Beale, T., Nunda, W. and van Wilgen, B.W. (2019). Distribution of invasive alien *Tithonia* (Asteraceae) species in eastern and southern Africa and the socio-ecological impacts of *T. diversifolia* in Zambia. *Bothalia* **49**, a2356, 11 pages. DOI: 10.4102/abc.v49i1.2356.

Yu, X.J., Hui, C., Sandhu, H.S., Lin, Z.Y. and Shi, P.J. (2019). Scaling relationships between leaf shape and area of 12 Rosaceae species. *Symmetry-Basel* **11**, 1255, 15 pages. DOI: 10.3390/sym11101255.

Yu, X.J., Shi, P.J., Hui, C., Miao, L.F., Liu, C.L., Zhang, Q.Y. and Feng, C.N. (2019). Effects of salt stress on the leaf shape and scaling of *Pyrus betulifolia* bunge. *Symmetry-Basel* **11**, 991, 15 pages. DOI: 10.3390/sym11080991.

Zhao, Z.H., Hui, C., Plant, R.E., Su, M., Carpenter, T., Papadopoulos, N., Li, Z.H. and Carey, J.R. (2019). Life table invasion models: spatial progression and species-specific partitioning. *Ecology* **100**, e02682, 11 pages. DOI: 10.1002/ecy.2682.

Zhao, Z.H., Hui, C., Plant, R.E., Su, M., Papadopoulos, N.T., Carpenter, T.E., Li, Z.H. and Carey, J.R. (2019). The failure of success: cyclic recurrences of a globally invasive pest. *Ecological Applications* **29**, e01991, 12 pages. DOI: 10.1002/eap.1991.

Zhao, Z.-H., Hui, C., Reddy, G.V.P., Ouyang, F., Men, X.-Y. and Ge, F. (2019). Plant species richness controls arthropod food web: evidence from an experimental model system. *Annals of the Entomological Society of America* **112**, 27-32.

Zylstra, M., Esler, K., Knight, A. and Le Grange, L. (2019). Integrating multiple perspectives on the human-nature relationship: a reply to Fletcher 2017. *The Journal of Environmental Education* **50**, 1-10.

Products, artefacts and patents

None

Conferences attended

International plenary/keynote addresses

Kumschick, S. 2019. Comparing impact of biological invasions across taxa and habitats using impact scoring schemes. Ecological Society of America Annual Meeting, Louisville, KY, USA, August 2019 (Kumschick)

Measey, J. 2019. Anfíbios invasores: uma visão da África austral sobre oportunidades e insights. 9th Brazilian Congress of Herpetology Campinas, Brazil. July 2019 (Measey)

Measey, J. The future of our planet's amphibians and reptiles: a view from invasion science XX European Congress of Herpetology, Milan 2-6 September 2019 (Measey)

Terblanche, J.S. 2019. Metabolic flexibility and costs of digestion in variable environments. Gordon Research Conference Plant-Herbivore Interactions, California, USA, March 2019. John Wilson, Southern African Plant Invaders Atlas (2019). EU COST Action CA17122—Alien CSI, Akrotiri Environmental Education Centre, Akrotiri, Cyprus, 25–28 February. [Invited talk] (Wilson)

National plenary/keynote addresses

None

International oral contributions

Broom, C.J., Castañeda, R.A., Weyl, O.L.F. 2019. Native fish recovery following the eradication of alien smallmouth bass from the Rondegat River. 8th World Conference on Ecological Restoration, Cape Town.

Constant N.L., Swanepoel L., Soarimalala V., Goodman S.M., Taylor P.J., Belmain S. A comparative study of the characterisation, impacts and locally-adapted management strategies of rodent pests in rural Afro-Malagasy farming communities. 13th African Small Mammal Symposium, Mekelle, Ethiopia, September, 2019 (Taylor)

Clusella-Trullas S. Exploring behavioral thermoregulation as a key moderator of climate change impacts. 2019. Institut de Recherche sur la Biologie de l'Insecte (IRBI-CNRS) Tours, France, 4th July (Clusella-Trullas).

Davies, S.J., Bell, J.J.A., Impson, D., Mabin, C., Meyer, M., Rhoda, C., Stafford, L., Stephens, K., Tafeni, M., Turner, A.A., Van Wilgen, N.J., Wilson, J.R.U., Wood, J., Measey, J. 2019. Coordinating invasive alien species management in a biodiversity hotspot: The CAPE Invasive Alien Animals Working Group. 18th African Amphibian Working Group, George Botanical Garden, South Africa. 7-8 October 2019.

Esler, K.J., Jacobs, S.J. 2019. Riparian restoration in fynbos catchments. 8th World Conference on Ecological Restoration, Cape Town South Africa, September 24-28 (Esler).

Faulkner, K.T., Robertson, M.P., Wilson, J.R.U. 2019. Stronger regional biosecurity is essential to prevent hundreds of harmful biological invasions. 15th Conference on Ecology and Management of Alien Plant invasions, 9-13 September 2019. Prague. (Robertson)

Foxcroft, L.C., MacFadyen, S., Pyšek, P., Richardson, D.M., Hui, C. 2019. Exploring patterns of alien plant invasions in Kruger National Park. 17th Annual International Savanna Science Networking Meeting, Skukuza, March 2019 (Foxcroft)

Foxcroft, L.C., MacFadyen, S., Pyšek, P., Richardson, D.M., Hui, C. 2019. Patterns and implications of alien plant invasions at multiple scales. International Ecology and Management of Alien Plant Invasions Conference, Prague, September 2019 (Foxcroft)

Garcia, R.A., Morran, E. and Clusella-Trullas, S. 2019. Imprints of physiological and ecological constraints on the biogeography of an ectotherm. “Species on the Move” international conference, July 2019, Kruger Park, South Africa. (Garcia).

Ginal, P. Herrel, A., Measey, J., Mokhatla, M., Rodder, D. 2019 Ecophysiology predicts the fundamental niche of native and invasive populations of the African clawed frog *Xenopus laevis*. XX European Congress of Herpetology, Milan 2-6 September 2019 (Measey)

Herrel, A., A.C. Fabre, P. Zablocki-Thomas, R. Boistel, G.J. Measey, A.Y. Dollion, A.M. Luger, D. Adriaens, C.V. Anderson and K.A. Tolley. 2019. Manual and Tail Prehensile Systems in Vertebrates: Performance and Morphology. 12th International Congress of Vertebrate Morphology Prague, Czech Republic. July 2019 (Measey)

Holmes, P., Esler, K.J., Richardson, D. 2019. The potential for passive restoration in alien plant-invaded ecosystems in the Cape Floristic Region (CFR). 8th World Conference on Ecological Restoration, Cape Town South Africa, September 24-28 (Holmes).

Mbambala, S., Tshisikhawe, P., Rahlao, S., Taylor, P. J. Roads, rivers and human settlements, rather than ecological niche, determine the recent spread of the Apple of Sodom (*Calotropis procera*) in Northern Limpopo Province, South Africa. African Conference for Linear Infrastructure and Ecology, Skukuza, Kruger National Park, March 2019 (Taylor)

Midgley, S., Esler, K.J., Holden, P., Methner, N., Rebelo, A., Stuart-Hill, S. 2019. Typologies and outcomes of ecological infrastructure restoration investment models. 8th World Conference on Ecological Restoration, Cape Town South Africa, September 24-28 (Midgley).

Mohanty, NP, Hui, C, Measey, J 2019 Invasion dynamics of an amphibian with frequent human-mediated translocations on the Andaman archipelago. Island Biology, La Réunion 8-13 July 2019. (Measey)

Mokhatla, M.M., Rodder, D., Measey, J. 2019 Using physiology and performance to predict climate driven distribution range shifts in three temperate African anurans species: a hybrid modelling approach. Species on the Move September 2019, Kruger National Park (Measey)

Mokotjomela, T.M., Xivuri, T.M., Jaca, T. (2019) Management of invasive alien plants in arid areas: importance of awareness and intervention strategies. 54th Grasslands Society Symposium for southern Africa, Northern Cape: Upington, Jun 30 - Jul 04, 2019.

Mokotjomela, T.M., Xivuri, T.M., Jaca, T. (2019) Detection of new cactus species and populations in arid areas of South Africa: potential impacts and management interventions. 54th Grasslands Society Symposium for southern Africa, Northern Cape: Upington, Jun 30 - Jul 04, 2019

Mokotjomela, T.M., Nemurangoni, T., Xivuri, T.M., Jaca, T. (2019) The role of solid waste dumping sites in early detection of emerging alien plant species in South Africa. 54th Grasslands Society Symposium for southern Africa. Northern Cape: Upington, Jun 30 - Jul 04, 2019

Ramahlo, M., Pirk, C.W.W., Ganswindt, A., Chimimba, C.T. 2019. Land use and human population density are drivers of biological invasion: Invasive *Rattus rattus* vs indigenous *Micaelamys namaquensis*. 11th International Symposium of Integrative Zoology, December 2019 (Chimimba)

Ruwanza, S. 2019. Secondary invasion: The need for a proper river restoration management plan. 8th World Conference on Ecological Restoration (SER 2019), 24-28 September 2019, South Africa. (Ruwanza)

Ruwanza, S. 2019. From natural to degraded ecosystems and back again. 2nd South Africa - Sweden University Research and Innovation Forum (SASUF 2019), 8-10 May 2019, South Africa. (Ruwanza)

Shackleton, R.T., Foxcroft, L.C., Pyšek, P. Wood, L.E., Bertzky, B., Bunbury, N., Jäger, H., Smith, K., van Merm, R., Witt, A., Wilson, J.R.U., Richardson, D.M. 2019. Assessing biological invasions in protected areas. International Ecology and Management of Alien Plant Invasions Conference, Prague, September 2019 (Foxcroft)

Te Beest, M., Thwala, T., Eppinga, M, Foxcroft, L.C. 2019. Determinants of spread of an emerging population of *Parthenium hysterophorus* in Kruger National Park. 17th Annual International Savanna Science Networking Meeting, Skukuza, March 2019 (Foxcroft)

Terblanche, J.S. 2019. Insect water balance: the final frontier. Institut de Recherche de la Biologie sur Insecte (IRBI), University of Tours, France. (invited lecture). (Terblanche)

Terblanche, J.S. 2019. Mechanisms underlying low temperature performance of insects and potential methods for manipulating field performance IAEA CRP meeting, University of Thessaloniki, Greece. (invited lecture). (Terblanche)

Terblanche, J.S. 2019. Metabolic flexibility and the costs of digestion in variable environments. 2019. INRA, Orleans, France. (invited lecture). (Terblanche)

Vimercati, G., Davies, S., Measey, J. 2019 Invasive subtropical toads allocate more resources to growth and maintenance over reproduction and storage in a mediterranean environment. XX European Congress of Herpetology, Milan 2-6 September 2019 (Measey)

Weier, S. M., Linden, V. M. G. Grass, I., Moodley, Y., Fraser, M., Tscharntke, T. Taylor, P. J. Land use and insect pest consumption by bats in macadamia orchards, South Africa. 18th International Bat Research Conference, Phuket, Thailand, July/August 2019 (Taylor)

Weyl, O.L.F. 2019. Understanding anglers is essential for managing alien invasive fishes in South Africa. American Fisheries Society, The Wildlife Society Joint Conference, Reno, Nevada, USA. (Weyl)

Weyl, O.L.F. 2019. Impacts of alien invasive species on aquatic ecosystems in South Africa. 8th World Conference on Ecological Restoration, Cape Town.

Wilson, J. R. 2019 South Africa as a national indicator case study. sTWIST 2nd meeting "Theory and Workflows for Alien and Invasive Species Tracking", iDiv, Leipzig, Germany, 3–7 June. (Wilson) [talk as part of working group]

Wilson, J. R. 2019 Invasion frameworks: an assessment of usage and options for improvement. 15th International Conference on Ecology and Management of Alien Plant Invasions, Prague, Czech Republic. 9–13 September. (Wilson)

National oral contributions

Allen, B.L., Allen, L.R., Ballard, G., Drouilly, M., Fleming, P.J.S., Hampton, J.O., Hayward, M.W., Kerley, G.I.H., Meek, P.D., Minnie, L., O'Riain, M.J., Parker, D.M., Somers, M.J. Animal welfare considerations for using large carnivores and guardian dogs as vertebrate biocontrol tools against other animals. Southern African Wildlife Management Association Annual Conference, Wilderness, South Africa, September 2019.

Alujević K., Logan M., Streicher J., Clusella-Trullas S. Integration of thermal sensitivity into the pace of life syndrome in the lizard *Agama atra*. University of Mpumalanga, Skukuza, Kruger National Park, 7-10 July 2019 (Alujević)

Becker, F., Slingsby, J., Measey, J., Tolley, K., and Altwegg, R. 2019. Searching for rare species and determining their absence for conservation applications. 18th African Amphibian Working Group, George, South Africa.

Bell, J. and Measey, J. 2019. Exploring time, effort and efficacy of Guttural Toad (*Sclerophrys gutturalis*) extirpation efforts in Constantia, Western Cape, South Africa. The National Symposium on Biological Invasions 15–17 May, 2019, Tulbagh (Measey)

Bitani, N., Downs, C.T. 2019. Dispersal of invasive *Lantana camara* by native bird species in KwaZulu-Natal, South Africa. 10th Oppenheimer Research Conference, Johannesburg, 3-4 October 2019.

Bitani, N., Downs, C.T. 2019. Dispersal of invasive *Lantana camara* by native bird species in KwaZulu-Natal, South Africa. Fountainhill Research Symposium, Wartburg, 9 – 10 October 2019.

Bitani, N., Downs, C.T. 2019. Dispersal of invasive *Lantana camara* by native bird species in KwaZulu-Natal, South Africa. ZSSA Conference, Skukuza, Kruger National Park, 7 - 10 July 2019.

Bitani, N., Downs, C.T. 2019. Dispersal of invasive *Lantana camara* by native bird species in KwaZulu-Natal, South Africa. The National Symposium on Biological Invasions 15 – 17 May 2019 Waterval, Tulbagh, Western Cape.

Burness, A., Williams, V., and Byrne, M.J. (2019). An investigation of the international traditional medicine trade as an introduction pathway for alien and potentially invasive species, at the 45th Annual SAAB, AMA and SASSB Joint congress at the University of Johannesburg 2019.

Collop, A., Karsten, M., Terblanche, J.S., Clusella-Trullas, S. 2019. Population genetics of the Harlequin Ladybird, *Harmonia axyridis*, in South Africa. 21st National Congress of the Entomological Society of Southern Africa (ESSA), Durban, June 2019. (Terblanche/Clusella-Trullas)

Constant, N. L., Swanepoel, L. H., Taylor, P. J., Indigenous uses and cultural practices associated with small carnivores: Challenges and common grounds for biodiversity conservation in African agro-ecosystems. The Conservation Symposium, 4-8 November, St Ives, KwaZulu-Natal, South Africa. (Taylor)

Cowie B.W., Witkowski, E.T.F., Venter, N., Byrne. 2019. The future of Famine weed invasions in South Africa. The 46th National Symposium on Biological Invasions, 15-17 May 2019. Waterval Country Lodge, Tulbagh, South Africa.

Cuthbert, R.N., Dalu, T., Wasserman, R.J., Weyl, O.L.F., Callaghan, A., Froneman, P.W., Dick, J.T.A. 2019. Towards improved quantifications of interaction strengths in temporary ponds. 39th ZSSA Congress, Skukuza, Kruger National Park.

Dalu, T., Weyl, O.L.F. 2019. Ecosystem responses to rotenone treatment in two reservoirs in the Western and Northern Cape Provinces, South Africa. 39th ZSSA Congress, Skukuza, Kruger National Park.

Davies, S., Impson, D., Bell, J.A., Jurk-Mabin, C., Meyer, M., Rhoda, C., Stafford, L., Stephens, K., Tafeni, M., Turner, A.A., van Wilgen, N.J., Wilson, J.R., Wood, J., and Measey, J. 2019. Coordinating invasive alien species management in a biodiversity hotspot: The CAPE Invasive Alien Animals Working Group. 18th African Amphibian Working Group, George, South Africa.

Davies, S.J., Impson, D., Jurk-Mabin, C., Meyer, M., Rhoda, C., Stafford, L., Stephens, K., Tafeni, M., Turner, A.A., Van Wilgen, N.J., Wilson, J.R., Wood, J. and Measey, J. 2019. Co-ordinating alien animal control in the Cape Floristic Region. The National Symposium on Biological Invasions 15–17 May 2019, Tulbagh (Measey)

Du Plessis, D. and Msomi, L. 2019. Citizen science as tool for community engagement: Tales from the Iimbovane Project. South African Higher Education Community Engagement Forum (SAHECEF) Conference, University of Mpumalanga, Mbombela. December 2019.

Drude L, Marlin D and Byrne M. (2019). A pre-release survey of insect herbivores associated with Tamarix taxa in South Africa. 21st Conference of the Entomological Society of Southern Africa. 11 July 2019. 11 July, Coastlands Umhlanga Hotel and Convention Centre, KZN. South Africa.

Esler, K.J. 2019. The role of champions. Fynbos Forum, Baardskeedersbos. August 2019 (Esler).

Griffiths C.L., Janion-Scheepers C. Additions to the alien fauna of South Africa 2012-2019. National Symposium on Biological Invasions, Tulbagh, May 2019 (Griffiths)

Hlungwani, H.A., Sara, J.R., Marr, S.M., Weyl, O.L.F. 2019. Establishing the fisheries potential of Flag Boshielo Dam based on the combined data collected from Flag Boshielo and Loskop dams. SASAqS Congress 2019, Bela Bela.

Holmes, P., Esler, K.J., Geerts, S. 2019. Side-stepping ecological processes to scale up restoration. Fynbos Forum, Baardskeedersbos. August 2019 (Holmes, Esler).

Honiball, T-L., Somers, M.J., Fritz, H., Venter, J. A preliminary assessment of spotted hyaena (*Crocuta Crocuta*) density within Madikwe Game Reserve. Southern African Wildlife Management Association Annual Conference, Wilderness, South Africa. September 2019.

Jubase, N., Measey, J. and Shackleton, R. 2019. A review of invasive species reporting by citizens using different platforms. The National Symposium on Biological Invasions 15–17 May 2019, Tulbagh (Measey)

Kajee, M., Dallas, H.F., Shelton, J.M., Griffiths, C.L. 2019. The status, distribution and abundance of South African freshwater fishes: A prelude to predicting the impacts of climate change on selected South African freshwater fish. 39th Zoological Society of Southern Africa (ZSSA) Congress, Skukuza, Kruger National Park, July 2019 (Griffiths)

Karsten, M., Terblanche, J.S. 2019. False codling moth *Thaumatotibia leucotreta* (Lepidoptera: Totricidaea): an overview of current interdisciplinary research. 21st National Congress of the Entomological Society of Southern Africa (ESSA), Durban, June 2019. (Terblanche)

Khosa, D., South, J., Wasserman, R.J., Weyl, O.L.F. 2019. Does habitat structure mitigate predation impact of *Micropterus salmoides* and *Micropterus floridanus*? 39th ZSSA Congress, Skukuza, Kruger National Park.

Kruger, N., Secondi, J., du Preez, L., Herrel, A. and Measey, J. 2019. The local adaptation of development and survival of native *Xenopus laevis* tadpoles in different climatic regions in South Africa.18th African Amphibian Working Group, George, South Africa.

Lamb, C., Faulkner, K.T., Robertson, M.P. 2019. The potential global and South African distribution of the emerald ash borer. The National Symposium on Biological Invasions, 15–17 May, 2019, Waterval Country Lodge, Tulbagh. (Robertson)

Lamb, C., Faulkner, K.T., Robertson, M.P. 2019. The potential global and South African distribution of the emerald ash borer, *Agrilus planipennis Fairmaire*, (Coleoptera: Buprestidae). 21st Congress of the Entomological Society of Southern Africa, 8–11 July 2019, Coastlands Umhlanga Hotel and Conference Centre, Umhlanga, South Africa. (Robertson)

Lehman, T., Esler, K.J., Holmes, P., Geerts, S. 2019. Exploring the concept of applied nucleation as a restoration tool in previously invaded Cape Flats Sand Fynbos in the Blaauwberg Nature Reserve, South Africa. Fynbos Forum, Baardskeedersbos. August 2019 (Lehman).

Linden, V. M G., I. Grass, E. Joubert, T. Tscharntke, S.M. Weier, P.J. Taylor. Ecosystem services and disservices by birds, bats and monkeys change with macadamia landscape heterogeneity. 39th ZSSA Symposium, Skukuza, Kruger NP, 7-10 July, 2019 (Taylor)

Madzivanzira, T.C., Barkhuizen, L.M., South, J., Weyl, O.L.F. 2019. Controlling of the Louisiana red swamp crayfish *Procambarus clarkii* (Crustacea, Decapoda) populations in the Free State Province using various eradication methods. 39th ZSSA Congress, Skukuza, Kruger National Park.

Maligana, N., Downs. C.T. 2019. The sale of exotic small mammal pets in South Africa. 10th Oppenheimer Research Conference, Johannesburg, 3-4 October 2019.

Maligana, N., Downs. C.T. 2019. The sale of exotic small mammal pets in South Africa. The National Symposium on Biological Invasions 15 – 17 May 2019 Waterval, Tulbagh, Western Cape.

Marneweck, D.G., Druce, D.J., Kelly, C., Somers, M.J. Effects of space use on fitness in African wild dogs. Southern African Wildlife Management Association Annual Conference. Wilderness, South Africa. September 2019.

Masibulele, X.M., Carvalho, F., Somers, M.J., Do Linh San, E. Latrine use by syntopic small-spotted and Cape genets: who visits, when, and to do what? 39th Zoological Society of Southern Africa, Skukuza, South Africa. July 2019.

Mayonde, S., Paterson, I.D. and Byrne, M.J. (2019). Molecular genetics investigation of *Opuntia engelmannii* – implications for biocontrol. The 46th National Symposium on Biological Invasions, 15-17 May 2019. Waterval Country Lodge, Tulbagh, South Africa.

Measey, J. 2019. Rapid adaptation of an invasive African toad: *Sclerophrys gutturalis*. 18th African Amphibian Working Group, George, South Africa.

Mokhatla, M., Rödder, D., and Measey, J. 2019. Using physiology and performance to predict climate driven distribution range shifts in three temperate African anurans species: a hybrid modelling approach. 18th African Amphibian Working Group, George, South Africa.

Mokotjomela, T.M., Xivuri, T.M., Jaca, T. (2020) Management of invasive alien plants in arid areas: importance of awareness and intervention strategies. 46th Annual conference of the South African Association of Botanists (SAAB) 7-10 January 2020 QwaQwa Campus, University of the Free State.

Mokotjomela, T.M., Xivuri, T.M., Jaca, T. (2020) Detection of new cactus species and populations in arid areas of South Africa: potential impacts and management interventions. 46th Annual conference of the South African Association of Botanists (SAAB) 7-10 January 2020 QwaQwa Campus, University of the Free State.

Mokotjomela, T.M., Nemurangoni, T., Xivuri, T.M., Jaca, T. (2020) The role of solid waste dumping sites in early detection of emerging alien plant species in South Africa. 46th Annual conference of the South African Association of Botanists (SAAB) 7-10 January 2020 QwaQwa Campus, University of the Free State.

Mofu, L., Woodford, D.J., Wasserman, R.J., Dalu, T., Weyl, O.L.F. 2019. Gut content and stable isotope analyses to trace the feeding behaviour among four co-occurring fishes in man-made impoundments. 39th ZSSA Congress, Skukuza, Kruger National Park.

Msweli, L.S., Downs, C.T. 2019. Effects of indigenous southern African ungulates on seed dispersal and germination of the alien invasive lantana (*Lantana camara*) and bugweed (*Solanum mauritianum*): A pilot study. 10th Oppenheimer Research Conference, Johannesburg, 3-4 October 2019.

Msweli, L., Baltzinger, C., Zungu, M., Downs, C.T. 2019. Seed dispersal potential of alien invasive lantana (*Lantana camara*) by indigenous and exotic southern African ungulates. Fountainhill Research Symposium, Wartburg, 9 – 10 October 2019.

Msweli, L.S., Downs, C.T. 2019. Effects of indigenous southern African ungulates on seed dispersal and germination of the alien invasive lantana (*Lantana camara*) and bugweed (*Solanum mauritianum*): A pilot study. The National Symposium on Biological Invasions 15 – 17 May 2019 Waterval, Tulbagh, Western Cape.

Nelufule, T., Kumschick, S., Faulkner, K.T., Robertson, M.P., Wilson, J.R.U. 2019. Risks posed by alien terrestrial invertebrate species in the South African pet trade. 21st Congress of the Entomological Society of Southern Africa, 8–11 July 2019, Coastlands Umhlanga Hotel and Conference Centre, Umhlanga, South Africa. (Robertson)

Ngwenya, D., Esler, K.J., Holmes, P., Geerts, S. 2019. How to scale up active restoration: circumventing natural processes as a management tool in Sand Fynbos. Fynbos Forum, Baardskeedersbos. August 2019 (Ngwenya).

Pegg, J., Attwood, C., Baker, N., Impson, D., Lombard, A., Meyer, W., Smith, K., Weyl, O. 2019. Controlling invasive carp in a natural lake ecosystem – lessons in management. SASAqS Congress 2019, Bela Bela.

Pegg, J., Mabin, C.A., Khosa, D., Barkhuizen, L.M., Weyl, O.L.F. 2019. Common carp in South Africa – exploring invasion using formal and informal records. National Symposium on Biological Invasions, Tulbagh.

Pegg, J., Mabin, C.A., Khosa, D., Barkhuizen, L.M., Weyl, O.L.F. 2019. Common carp in South Africa – exploring invasion using formal and informal records. 39th ZSSA Congress, Skukuza, Kruger National Park.

Peta, S.T.P., Engelbrecht, G.D. and Measey, J. 2019. Reptile and bird diversity along a gradient of invasive alien plants in the threatened Woodbush Granite Grassland (Limpopo Province, South Africa). The National Symposium on Biological Invasions 15–17 May, 2019, Tulbagh (Measey)

Robertson, M.P., Bishop, T.R. 2019. Temporal changes in ant communities across an elevation gradient. 21st Congress of the Entomological Society of Southern Africa, 8–11 July 2019, Coastlands Umhlanga Hotel and Conference Centre, Umhlanga, South Africa. (Robertson)

Shivambu, C.T, Downs, C. T. 2019. Aspects of the ecology of the invasive rose-ringed parakeets (*Psittacula krameri*) in eThekwini Municipality. ZSSA Conference, Skukuza, Kruger National Park, 7 - 10 July 2019.

Shivambu, C.T, Downs, C. T. 2019. Aspects of the ecology of the invasive rose-ringed parakeets (*Psittacula krameri*) in eThekwini Municipality. The National Symposium on Biological Invasions 15 – 17 May 2019 Waterval, Tulbagh, Western Cape.

Shivambu, C.T, Downs, C. T. 2019. Aspects of the ecology of the invasive rose-ringed parakeets (*Psittacula krameri*) in eThekwini Municipality. 10th Oppenheimer Research Conference, Johannesburg, 3-4 October 2019.

Singh, G., Reynolds, C., Byrne, M., Rosman, B (2019) Waterbird Mediated Seed-dispersal of invasive species using satellite data and deep learning. The 46th National Symposium on Biological Invasions. 15-17 May 2019. Waterval Country Lodge, Tulbagh, South Africa.

South, J., Botha, T., Wolmarans, N., Wepener, V., Weyl, O. 2019. Assessing the effects of DDT on behavioural predator-prey interactions between *Xenopus laevis* and Culex sp. larvae. SASAqS Congress 2019, Bela Bela.

South, J., Weyl, O.L.F. 2019. Does intra-individual behaviour determine invasion success and ecological impact? SANBI Invasion Symposium 2019, Tulbagh

South, J., Weyl, O.L.F. 2019. Does intra-individual behaviour determine invasion success and ecological impact? 39th ZSSA Congress, Skukuza, Kruger National Park.

Stephens, K., Measey, J., Reynolds, C. and Le Roux, J.J. 2019. Impacts of invasive birds: assessing hybridisation between invasive Mallard Ducks (*Anas platyrhynchos*) and native Yellow-billed Ducks (*Anas undulata*) in South Africa. The National Symposium on Biological Invasions 15–17 May, 2019, Tulbagh (Measey)

Swanepoel, L. H., Swanepoel, C. M., Keith, M., Belmain, S., Roetter, R. R., Hoffmann, M. P., Taylor, P. J., Williams, S. Predation in agricultural rodent pest control: Underutilized ecosystem service or unrealistic expectation? 39th ZSSA Symposium, Skukuza, Kruger NP, 7-10 July, 2019 (Taylor)

Taylor, P. J., V.M.G. Linden, V. Mphethe, S. Weier. How resilient are bats to anthropogenic change? Land use effects on insectivorous bat ensembles in commercial and small-holder agricultural landscapes in Limpopo, South Africa. 39th ZSSA Symposium, Skukuza, Kruger NP, 8-10 July, 2019 (Taylor)

Taylor, P. J., Linden, V. M. G., Weier, S. M., Tscharntke, T., Grass, I. Nature's bounty requires wise stewardship: Bad agricultural practices in the macadamia industry can cause massive economic losses of bat and bird ecosystem services in pest control. The Conservation Symposium, 4-8 November, St Ives, KwaZulu-Natal, South Africa. (Taylor)

Van Wyk, A., Weyl, O.L.F., Bernard, A., Pegado, A., Hugo, S., Ngochera, M., Jonasse, C., Gobo, E. 2019. The potential of Baited Remote Underwater Video Systems (BRUVS) in Lake Malawi for the monitoring of *Chambo Oreochromis* (Nyasalapia) spp. SASAqS Congress 2019, Bela Bela.

Wasserman, R.J., Weston, M., Weyl, O.L.F., Froneman, P.W., Welch, R.J., Vink, T.J.F., Dalu, T. 2019. Sacrificial males: the potential role of copulation and predation in contributing to copepod sex-skewed ratios. 39th ZSSA Congress, Skukuza, Kruger National Park.

Weyl, O.L.F. 2019. Black Bass Micropterus spp. invasion status, impacts, fisheries and conflict management in South Africa. 39th ZSSA Congress, Skukuza, Kruger National Park.

Weyl, O.L.F., Barkhuizen, L., Christison, K., Cowx, I.G., Dalu, T., Hlungwani, H.A., Impson, D., Mandrak, N., Marr, S.M., Sankar, K., Sara, J.R., Smit, N., Tweddle, D., Vine, N., Wepener, V., Zvavahera, M. 2019. Opportunities, threats and research requirements for developing sustainable inland fisheries in South Africa. SASAqS Congress 2019, Bela Bela.

Weyl, O.L.F. 2019. Understanding anglers is essential for managing alien invasive fishes in South Africa. National Symposium on Biological Invasions, Tulbagh.

Wilson, J.R., Measey, J., Richardson, D.M., Van Wilgen, B.W. and Zengeya, T.A. 2019. Biological invasions in South Africa: potential futures. The National Symposium on Biological Invasions 15–17 May, 2019, Tulbagh (Measey)

Wilson, J. R. 2019 Biological invasions in South Africa: potential futures, National Symposium on Biological Invasions, 15–17 May, Tulbagh (speed talk)

Zengeya, T.A., Terrapon, H., Munyai, T., van Wilgen, B., Wilson, J.R. 2019. Facilitated workshop on data requirements for the second National Status Report on Biological Invasions, at the National Symposium on Biological Invasions, Tulbagh (Zengeya)

Zvavahera, M., Weyl, O.L.F., Hugo, S., Vine, N. 2019. Investigations into the effect of the environment on the life-history strategies and morphometric traits of the estuarine roundherring, *Gilchristella aestuaria* (Pisces Clupeidae). SASAqS Congress 2019, Bela Bela.

International posters

Mokotjomela, T.M., Xivuri, T.M., Manyama, P. Eradication of the emerging alien cactus species, *Cylindropuntia pallida* F.M. Knuth, and active restoration in arid areas of South Africa. 8th World Conference: Ecological Restoration. Cape Town, South Africa, 24-28 September 2019.

Ntloko, B., Siebert, S., Mokotjomela, T.M. Restoration of kimberlite tailings with native grassland vegetation in the Afro-alpine zone, Lesotho. 8th World Conference: Ecological Restoration. Cape Town, South Africa, 24-28 September 2019.

Ngwenya, D., Esler, K.J., Holmes, P., Geerts, S. 2019. How to scale up active restoration: circumventing fire in Cape Fynbos restoration as a case study. 8th World Conference on Ecological Restoration, Cape Town South Africa, September 24-28.

Ramahlo, M., Chimimba, C.T., Pirk, C.W.W., Ganswindt, A. 2019. Non-invasive monitoring of adrenocortical activity in free-ranging Namaqua rock mice *Micaelamys namaquensis* as a measure of ecosystem health. International Society for Wildlife Endocrinology. Skukuza, Kruger National Park, October 2019.

Van Zitters, M., Esler, K.J., Rebelo, A., Mingo, J. 2019. Active rehabilitation following alien clearing in the Berg and Breede catchments, Western Cape. 8th World Conference on Ecological Restoration, Cape Town South Africa, September 24-28.

National posters

Allsopp, N., Slingsby, J., Esler, K.J. 2019. Research questions for the conservation of the Cape Floristic Region. Fynbos Forum, Baardskeedersbos. August 2019.

Cowie B.W., Witkowski, E.T.F., Venter, N., Byrne. 2019. The revival of Bugweed biocontrol in South Africa: a promising future ahead? 45th Conference of the South African Association of Botanists, University of Johannesburg, Johannesburg, 9-11 January

Gumede, T., Downs, C.T. 2019. Sugar preference of invasive Common Myna (*Sturnus tristis*). ZSSA Conference, Skukuza, Kruger National Park, 7-10 July 2019.

Honiball, T-L., Somers, M.J., Fritz, H., Venter, J. A preliminary assessment of spotted hyaena (*Crocuta Crocuta*) density within Madikwe Game Reserve. 10th Oppenheimer Research Conference. Midrand, South Africa. October 2019.

Javal, M., Chapuis, M.-P., Benoit, L., Smit, C., Conlong, D.E., Terblanche, J.S. Does host plant drive variations in microbial gut communities in a recently shifted pest? 21st National Congress of the Entomological Society of Southern Africa (ESSA), Durban, June 2019. (Terblanche)

Madzivanzira, T.C., South, J., Nhiwatiwa, T., Weyl, O.L.F. 2019. Standardisation of *Cherax quadricarinatus* sampling gear and abundance data in southern Africa. 39th ZSSA Congress, Skukuza, Kruger National Park.

Maligana, N., Downs. C.T. 2019. The sale of exotic small mammal pets in South Africa. ZSSA Conference, Skukuza, Kruger National Park, 7-10 July 2019.

Msweli, L.S., Downs, C.T. 2019. Effects of indigenous southern African ungulates on seed dispersal and germination of the alien invasive lantana (*Lantana camara*) and bugweed (*Solanum mauritianum*): A pilot study. ZSSA Conference, Skukuza, Kruger National Park, 7-10 July 2019.

Singh, G., Reynolds, C., Byrne, M., Rosman, B. 2019. Shift Happens. Deep Learning Indaba X South Africa 14-17 April 2019. University of KwaZulu-Natal, Howard campus

Smit, C., Javal, M., Lehmann, P., Conlong, D.E., Terblanche, J.S. Determination of potential host plants, and the metabolic costs of digestion on alternate hosts, in an emerging pest of sugarcane, *Cacosceles newmannii* (Cerambycidae) 21st National Congress of the Entomological Society of Southern Africa (ESSA), Durban, June 2019. (Terblanche)

Education and training

Students supported by the Centre in 2019

Name	Citizenship	Institution	Race	Gender	Status	Funding level*
BSc (Honours)/4th year B. Agric.						
Ms Thandeka Mahlobo	South African	University of KwaZulu-Natal	Black	F	Completed	Full
Ms Welri Nortje	South African	Stellenbosch University	White	F	Completed	Independent
Ms Margo Paterson	South African	Stellenbosch University	White	F	Completed	Independent
Ms Tashreeqah Sadan	South African	Cape Peninsula University of Technology	Coloured	F	Completed	Independent
Masters						
Ms Staci Warrington	South African	Stellenbosch University	White	F	Continuing	Full
Ms Sinenhlahla Mntambo	South African	University of KwaZulu-Natal	Black	F	Continuing	Full
Ms Nolwethu Jubase	South African	Stellenbosch University	Black	F	Continuing	Independent
Ms Catherine Wagener	South African	Stellenbosch University	White	F	Continuing	Full
Ms Thembeka Thwala	South African	University of Venda	Black	F	Continuing	Independent
Mr Peter Mochechela	South African	University of Fort Hare	Black	M	Continuing	Partial
Ms Ncumisa Matam	South African	Rhodes University	Black	F	Continuing	Partial
Mr Christopher Delport	South African	Stellenbosch University	White	M	Resigned	Partial
Ms Kiosha Bhikraj	South African	University of KwaZulu-Natal	Indian	F	Continuing	Partial
Mr Lehlohonolo Adams	South African	University of the Free State	Black	M	Continuing	Partial
Ms Lucia Mokubedi	South African	University of Cape Town	Black	F	Continuing	Full
Mr Tshililo Kharivha	South African	Rhodes University	Black	M	Continuing	Full
Ms Aneesa Du Plessis	South African	Cape Peninsula University of Technology	Coloured	F	Continuing	Full
Ms Melissa Ewels	South African	Stellenbosch University	White	F	Continuing	Independent
Ms Nicole Vorster	South African	Stellenbosch University	White	F	Upgraded to PhD	Full
Mr Bhongolethu Mtengwana	South African	University of the Western Cape	Black	M	Continuing	Full
Ms Lee-Anne Botha	South African	University of Pretoria	Coloured	F	Continuing	Full
Ms Ashleigh Basel	South African	Stellenbosch University	White	F	Continuing	Independent
Ms Nasiphi Bitani	South African	University of KwaZulu-Natal	Black	F	Submitted	Independent

Name	Citizenship	Institution	Race	Gender	Status	Funding level*
Ms Lindelwa Msweli	South African	University of KwaZulu-Natal	Black	F	Continuing	Partial
Mr Nkosinathi Ntuli	South African	Nelson Mandela University	Black	M	Continuing	Full
Ms Amy Collop	South African	Stellenbosch University	Coloured	F	Continuing	Full
Mr Luca Afonso	South African	Stellenbosch University	White	M	Pending overtime	Independent
Ms Aviwe Homani	South African	Stellenbosch University	Black	F	Continuing	Full
Mr Tevan Lehman	South African	Stellenbosch University	White	M	Continuing	Independent
Ms Monique Van Zitters	South African	Stellenbosch University	Coloured	F	Continuing	Partial
Mr Malukhanye Mbopha	South African	Stellenbosch University	Black	M	Completed	Independent
Ms Thabang Sibiya	South African	Stellenbosch University	Black	F	Completed	Independent
Ms Anneke Schoeman	South African	University of the North West	White	F	Upgraded to PhD	Full
Ms Puseletso Motsomane	South African	University of Pretoria	Black	F	Resigned	Partial
Ms Mancha Ramotjiki	South African	University of Venda	Black	F	Thesis submitted	Partial
Ms Dianah Kutama	South African	Stellenbosch University	Black	F	Completed	Independent
Ms Ella Morran	South African	Stellenbosch University	White	F	Completed	Independent
Mr Kyle Boast	South African	Stellenbosch University	White	M	Continuing	Full
PhD-Upgrade						
Ms Lisa Skein	South African	Stellenbosch University	White	F	Completed	Full
Ms Anneke Schoeman	South African	University of the North West	White	F	Continuing	Full
PhD						
Ms Patricia Duncan	South African	Stellenbosch University	White	F	Current	Independent
Ms Natasha Kruger	South African	Stellenbosch University	White	F	Thesis submitted	Partial
Mr Dumisani Khosa	South African	Rhodes University	Black	M	Continuing	Independent
Mr Lubabalo Mofu	South African	Rhodes University	Black	M	Continuing	Independent
Mr Beka Nxele	South African	Stellenbosch University	Black	M	Continuing	Independent
Mr Anthony Mapaura	Zimbabwe	University of the Free State	Black	M	Continuing	Partial
Ms Uviwe Bolosha	South African	Rhodes University	Black	F	Continuing	Full
Mr Phikolomzi Matikinca	South African	Stellenbosch University	Black	M	Continuing	Independent
Ms Emily Joy Jones	South African	Nelson Mandela University	White	F	Continuing	Full
Mr Thozamile Yapi	South African	Rhodes University	Black	M	Continuing	Independent
Ms Lerato Maimela	South African	University of Pretoria	Black	F	Continuing	Independent

Name	Citizenship	Institution	Race	Gender	Status	Funding level*
Ms Ndivhuwo Maligana-Shivambu	South African	University of KwaZulu-Natal	Black	F	Continuing	Partial
Mr Cavin Shivambu	South African	University of KwaZulu-Natal	Black	M	Continuing	Partial
Ms Sinazo Ntsonge	South African	Rhodes University	Black	F	Continuing	Full
Ms Maria Castillo	Chile	Stellenbosch University	White	F	Completed	Independent
Ms Henrika Bosua	South African	Stellenbosch University	White	F	Continuing	Full
Ms Davina Saccaggi	South African	Stellenbosch University	White	F	Continuing	Partial
Ms Tumeka Mbobo	South African	Stellenbosch University	Black	F	Continuing	Independent
Mr Brent Abrahams	South African	Stellenbosch University	Coloured	M	Continuing	Independent
Ms Duduzile Ngwenya	Zimbabwe	Stellenbosch University	Black	F	Continuing	Independent
Mr Blair Cowie	South African	University of Witwatersrand	White	M	Continuing	Full
Ms Jeanne Mukarugwiro	Rwanda	University of Witwatersrand	Black	F	Submitted	Independent
Ms Mmatsawela Ramahlo	South African	University of Pretoria	Black	F	Continuing	Full
Ms Karla Alujevic	Croatian	Stellenbosch University	White	F	Completed	Independent

*Funding is categorised as full (student is fully supported with bursary and running costs supplied at standard CoE levels), partial (in the form of a full or partial bursary or 'top-up', or running costs only) and independent (funding comes entirely from other sources, but the student is supervised by a core team member).

Post-doctoral associates supported in 2019

Post-doctoral associates are early career researchers engaged on two-year fellowships to focus on research deliverables such as peer-reviewed publications, organizing workshops and journal special issues, and often play a key role in student training.

Name	Citizenship	Institution	Race	Gender	Status	Funding
Dr James Baxter-Gilbert	Canada	Stellenbosch University	White	M	Continuing	Full
Dr Nitya Mohanty	India	Stellenbosch University	Indian	M	Resigned post-doc	Independent
Dr Josie South	United Kingdom	South African Institute for Aquatic Biodiversity	Coloured	F	Continuing	Independent
Dr Sanet Hugo	South African	South African Institute for Aquatic Biodiversity	White	F	Resigned post-doc	Independent
Dr Sean Marr	South African	South African Institute for Aquatic Biodiversity	White	M	Resigned post-doc	Independent
Dr Tainã Loureiro	Brazil	Stellenbosch University	White	F	Continuing	Full
Dr Koebraa Peters	South African	Stellenbosch University	Coloured	F	Resigned	Full
Dr Jan-Hendrik Keet	South African	Stellenbosch University	White	M	Continuing	Full
Dr Mlungele Nsikani	Zimbabwe	Stellenbosch University	Black	M	Continuing	Full
Dr Heidi Hirsch	Germany	Stellenbosch University	White	F	Continuing	Independent
Dr Quentin Willot	Belgian	Stellenbosch University	White	M	Continuing	Partial
Dr Arunava Datta	India	Stellenbosch University	Indian	M	Continuing	Independent
Dr Katelyn Faulkner	South African	University of Pretoria	White	F	Resigned post-doc	Independent
Dr Raquel Garcia	Portugal	Stellenbosch University	White	F	Resigned post-doc	Independent

* Funding is categorised as full (post-doc is fully supported with bursary and running costs supplied at standard COE levels), partial (in the form of a full or partial bursary or 'top-up', or running costs only) and independent (funding comes entirely from other sources, but the post-doc is hosted by a core team member).

Networking

Academic visitors to core team members

Prof. Sven Bacher, Dr Giovanni Vimercati, and Lara Volery, University of Fribourg, Switzerland. *Collaborator on Socio Economic Impact Classification for Alien Taxa* (Kumschick)

Dr Duan Biggs, Environmental Futures Research Institute, Griffiths University, Australia. *Collaborator on biodiversity scenarios* (Richardson)

Dr Alessandra-Maria Bissattini, Università Degli Studi Roma Tre, Rome (UNIROMA3), Department of Biology, Italy. *Collaborator on detection of frog density using aSCR* (Measey)

Prof. Stefane Boissinot, NYU Abu Dhabi. *Collaborator on 'Lizard genomics across Africa'* (Clusella-Trullas); and

Prof. Stephane Boissinot, New York University in Abu Dhabi, Evolutionary Genomics Lab. *Collaborator on genomics of African clawed frogs* (Measey)

Prof. Robert Britton, Department of Life and Environmental Sciences Bournemouth University Poole. *Collaborator on Functional responses in aquatic ecosystems* (Weyl)

Prof. James Carey, Department of Entomology, University of California, Davis, USA. *Collaborator (discussions) on modelling invasive species* (Richardson)

Prof. Steven Chown, Department of Biological Sciences, Monash University, Australia. *Discussions on invasive species research and monitoring transects* (Davies, Richardson)

Mr Ross Cuthbert, Queens University Belfast, School of Biological Sciences. *Collaborator on Functional responses in aquatic ecosystems* (Weyl)

Pauline Dufour, PhD student, University of Hong Kong. *Collaborator on (project) 'Climate change implications of nocturnality'* (Clusella-Trullas)

Mr James Fantom, St Helena Trust, St Helena Island. *Collaborator on biological invasions on islands* (Davies, Measey, Richardson)

Dr Mesfin Gossa (post-doctoral fellow) from Forestry and Agricultural Biotechnology Institute, visited Free State National Botanical Garden to give a *presentation on Polyphagous Shot Hole Borer* during the Plant Sale Expo and to *inspect Free State National Botanical Garden for tree diseases* (Mokotjomela)

Prof. Matt Hayward, University of Newcastle, School of Environmental and Life Sciences. *Collaborator on the project "Improved food security and biodiversity outcomes go hand-in-hand"* (Somers)

Prof. Fangliang He, Canadian Research Chair in Biodiversity and Landscape Modelling, University of Alberta, Canada. *Collaborator on modelling of biological invasions* (Hui, Richardson)

Dr Dan Hoops, University of Toronto. *Collaboration on the invasive nature of toads brains* (Baxter-Gilbert) (Measey lab)

Dr Sabrina Kumschick, Centre for Invasion Biology (C·I·B), Department of Botany and Zoology, Stellenbosch University, and Invasive Species Programme, South African National Biodiversity Institute. *Collaborator on an alien species risk analysis framework for South Africa and applications for Kruger National Park* (Foxcroft)

Mr Daniel Lins (PhD student from Federal University of Paraná, Brazil) spent six months visiting and working with lab group (Robinson-Smythe)

Dr Carla Madelaire, Departamento de Fisiologia, Instituto de Biociências, Universidade de São Paulo, Brazil. *Collaborator on stress in invasive toads* (Measey)

Prof. Ara Monadjem, Department of Biological Sciences, University of Swaziland. *Collaborator on small mammal ecology* (Chimimba)

Michaël Nicolaï, PhD student, University of Gent, Belgium. *Collaborator on (project) 'Investigating the genetic mechanisms underlying nutrient-driven skin colour change in Agama atra using transcriptomics'* (Clusella-Trullas)

Dr Iain Paterson, Centre for Biological Control, Entomology and Zoology department, Rhodes University. *Collaborator on biological control of invasive alien plants in South African National Parks* (Foxcroft)

Dr Dean E. Pearson, Rocky Mountain Research Station, United States Forest Service, Missoula, USA. *Collaborator on challenges in restoring areas degraded by alien plant invasions* (Esler, Richardson)

Dr Anna Probert, University of Fribourg, Switzerland. *Collaboration on uncertainty in impact assessments* (Kumschick)

Prof. Petr Pyšek, Department of Invasion Ecology, Institute of Botany, Academy of Sciences of the Czech Republic, Průhonice, and Charles University in Prague, Czech Republic. *Collaboration on maintaining functionality of savanna ecosystems in Kruger National Park* (Foxcroft)

Prof. Andrew Robinson, Director, Centre of Excellence for Biosecurity Risk Analysis, University of Melbourne, Australia, visited the C·I·B and held a workshop with attendees from the C·I·B, various government departments (Departments of Environmental Affairs, Agriculture, Forestry and Fisheries, and Science and Technology) and SANBI on risk analysis with regards to regulations, specifically on alien and invasive species. He shared valuable insights from his experiences with regulatory bodies, specifically in Australia and New Zealand. (Kumschick, Richardson);

Dr Jean Secondi, University of Angers, Department of Biological Sciences. *Collaborator on African clawed frog invasions and co-supervisor of PhD candidate N. Kruger* (Measey)

Prof. Tony Ricciardi, Redpath Museum, McGill University. *Collaboration on functional responses in aquatic ecosystems* (Weyl)

Prof. Jay Stauffer, Penn State University, Pennsylvania, USA. *Collaborator on African Great Lakes research* (Weyl)

Dr R.J. Wassermann, Botswana International University of Science and Technology. *Collaborator on functional responses in aquatic ecosystems* (Weyl)

Academic visits by core team members to other institutions

Coventry University Centre for Agroecology, Water, and Resilience, U.K. *Developing collaboration on invasions in horticulture and agro-forestry and use of questionnaires with Dr Katherina Dehnen-Schmultz and Dr Jana Fried. Gave an invited lunchtime seminar "Monitoring and*

reporting on biological invasions" Tuesday 17 September, 2019. https://www.youtube.com/watch?v=nYqqcKuB7nU (Wilson)

Departamento de Fisiologia, Instituto de Biociências, Universidade de São Paulo, Brazil. *Collaboration on stress in invasive toads with Prof. Fernando Ribeiro Gomes* (Measey)

Department of Biological Sciences, University of Namibia, Windhoek, Namibia. *Collaboration on small mammal ecology with Prof. John Mfune* (Chimimba)

Department of Entomology and Fisheries Sciences, College of Natural Sciences, Makerere University, Uganda (also accompanied by Prof. Matt Hayward, University of Newcastle, School of Environmental and Life Sciences, Australia). *Collaboration on project titled "Improved food security and biodiversity outcomes go hand-in-hand" with Dr Tutilo Mudumba* (Somers)

Department of Invasion Ecology, Institute of Botany, Academy of Sciences of the Czech Republic, Průhonice, and Charles University in Prague, Czech Republic. *Collaboration on maintaining functionality of savanna ecosystems in Kruger National Park with Prof. Petr Pyšek* (Foxcroft)

Department of Plant Biology, University of Vermont, Burlington, VT, USA. Meetings with many faculty members and students on many aspects of plant invasion ecology and invasions (Hui, Richardson)

Division of Science and Technology, African Union Head Office, Addis Ababa, Ethiopia. *Discussions on funding opportunities for research on biological invasions in Africa* (Richardson)

Eagle Fish Genetics Lab, Idaho Department of Fish and Game, Idaho. *Collaboration on invasive fishes with Dr John Hargrove and Dr Mathew Campbell* (Weyl)

Insect Biology Research Institute (IRBI-CNRS), Tours, France. *Collaboration on variability of microclimates across different landscapes with Prof. Sylvain Pincebourde* (Clusella-Trullas)

Institut de Recherche sur la Biologie de l'Insecte and University Francois-Rabelais, Tours, France. *Collaboration and sabbatical on galling insects on oak and beech trees with Prof. Sylvain Pincebourde* (Terblanche)

IUCN, Cambridge, UK. Collaboration on Environmental Impact Classification for Alien Taxa with Kevin Smith (Kumschick)

IUCN, Malaga, Spain. *Collaboration and course to conduct EICAT assessment under a EU Life Project with Catherine Numa* (Kumschick)

Awards to core team members

African Union Kwame Nkrumah Award for Scientific Excellence (Continental) (Richardson)

Cadotte Lab (Marc Cadotte) gave Duduzile Ngwenya a travel award to attend the GUBIC (urban invasions) meeting and a training workshop in Toronto in June 2019 (Esler) (https://www.utsc.utoronto.ca/projects/gubic/registration/ https://www.utsc.utoronto.ca/projects/gubic/2019/04/03/grad-student-training-workshop-offered-on-saturday-june-22-2019/)

C·I·B travel award (R30000) for the best PhD presentation at the 2019 C·I·B Annual Research Meeting (ARM), to Mr Blair Cowie (Byrne)

Honorary Assistant Professor in the School of Biological Sciences, The University of Hong Kong (2018-2022) (Clusella-Trullas)

Royal Museum of Central Africa (RMCA) travel grant for Lerato Maimela to attend a FishBase and Fish Taxonomy training course at the Royal Museum of Central Africa, Tervuren, Belgium (Zengeya)

Island Biology (organizers) award for N. Mohanty to attend Island Biology meeting in La Réunion (Measey)

Rhodes University Research Committee Travel Grant awarded to Dr Sheunesu Ruwanza to attend 8th World Conference on Ecological Restoration (SER 2019), South Africa (Ruwanza)

Royal Society of South Africa (Council Member 2014-2019; Vice President and Acting President in 2019) (Richardson)

Species on the Move travel award to post-doc Raquel Garcia to attend the conference in July 2019 in the Kruger Park, South Africa (Clusella-Trullas).

Stellenbosch University Africa collaboration grant for Dr J. Baxter-Gilbert to conduct fieldwork in Mauritius (Measey)

Stellenbosch University BRICS grant for J. Measey to attend meeting in Campinas, Brazil (Measey)

Stellenbosch University Research Excellence Award (Hui, Measey, Richardson)

World Congress of Herpetology (WCH) travel bursary to PhD student Karla Alujevic to attend the 2019 WCH in New Zealand (Clusella-Trullas).

Research collaborations

Acoustic monitoring of amphibians in the fynbos. Collaborators: Prof. Res Altwegg, Department of Statistical Sciences, University of Cape Town, South Africa; Dr David Borchers, School of Mathematics and Statistics, University of St Andrews, Scotland (Measey)

Advancing Towards a General Theory of Invasive Species Impacts: How Do Ecological Effects Vary Across Time and Space?: Luke Flory, University of Florida, USA; Julie Lockwood, Rutgers University, USA; Sean Menke, Lake Forest College, USA; Anibal Pauchard, Universidad de Concepción, Chile; Stephanie Green, University of Alberta, Canada. (Kumschick)

African Great Lakes research. Collaborator: Prof. Jay Stauffer, Penn State University, Pennsylvania, USA (Weyl)

Alien fouling associate with the culture of mussels. Collaborators: Prof. Rosana Rocha, Federal University of Paraná, Brazil; Mr Daniel Lins, Federal University of Paraná, Brazil (Robinson-Smythe)

Alien plant distribution in protected areas and evidence based management. Collaborators: Prof. Karen Esler, Conservation Ecology and Entomology, Stellenbosch University; Prof. Melodie McGeoch, School of Biological Sciences, Monash University, Australia; Dr Chad Cheney, Conservation Ecology and Entomology, Stellenbosch University; Dr Nicola van Wilgen, South African National Parks (Foxcroft)

Aquatic biology of freshwater systems. Collaborator: Professor Stephan Woodborne, iThemba Laboratories, University of the Witwatersrand, Johannesburg (Chimimba)

Biocontrol of alien weeds. Collaborator: Prof. Martin Hill, Rhodes University (Byrne)

Biocontrol of *Opuntia*. Collaborator: Dr Iain Paterson, Rhodes University (Byrne)

Biocontrol of Bugweed. Collaborator: Mr Hugh Gourlay, Landcare New Zealand (Byrne)

Biodiversity effects of animal burrows, 2016-2020. Collaborators: Maria Blanco-Perez, Imperial Collage, London; Maartin Strauss, University of South Africa; Mark Keith, University of Pretoria, Jan Venter, Nelson Mandela University (Somers)

Bugweed Remote Sensing. Collaborator: Dr Solomon Newete, ARC (Byrne)

Carnivores and people, 2017-2019 – Collaborators: Florence Weise, CLAWS conservancy; Matt Hayward, Newcastle University (Somers)

Carnivore Reintroduction Biology and effects on biodiversity, 2004-2020 – Collaborator: David Marneweck, Endangered Wildlife Trust; Dave Druce, Ezemvelo KZN Wildlife (Somers)

Cities as Hotspots for Invasions: The Case of eThekwini Municipality, Prof. Serban Proches, UKZN (Wilson)

Concepts in invasion ecology, diverse studies on plant invasion science. Collaborators: Prof. P. Pyšek, Dr J. Pergl, Academy of Sciences of the Czech Republic, Institute of Botany, Czech Republic (Richardson)

Concepts in invasion science. Collaborator: Prof. F. Essl, Division of Conservation Biology, Vegetation, and Landscape Ecology University of Vienna, Austria (Richardson)

Conservation monitoring of otters in South Africa, 2014-2019. Collaborator: Trevor McIntyre, University of South Africa (Somers)

Conflict species inland fisheries. Collaborator: Prof. Ian Cowx, Hull, Hull International Fisheries Institute, University of Hull (Weyl)

Climate change implications of nocturnality. Collaborator: Prof. Tim Bonebrake, School of Biological Sciences, University of Hong Kong (Clusella-Trullas).

Ecology and biocontrol of Bugweed (2). Collaborator: Prof. Ed Witkowski, Wits, APES (Byrne)

Ecology and biocontrol of Parthenium (2). Collaborator: Prof. Ed Witkowski, Wits, APES (Byrne)

Ecology and biocontrol of Lantana. Collaborator: Prof. Ed Witkowski, Wits, APES (Byrne)

Ecology of fishes. Collaborator: Prof. Jurgen Geist, Lehrstuhl für Aquatische Systembiologie, Technische Universität München (Weyl)

Ecosystem Research, IGB Leibniz-Institut of Freshwater Ecology and Inland Fisheries, Berlin, Germany.; Sven Bacher, Department of Biology, Unit Ecology and Evolution, University of Fribourg, Switzerland; Piero Genovesi, ISPRA (Institute for Environmental Protection and Research), Italy; Petr Pyšek, Institute of Botany, Academy of Sciences of the Czech Republic and Department of Ecology, Faculty of Science, Charles University in Prague, Czech Republic; Montserrat Vilà, Estación Biológica de Doñana (EBD-CSIC), Sevilla, Spain; John Wilson, SANBI and Centre for Invasion Biology, Stellenbosch University; Kevin Smith, IUCN, Cambridge, UK (Kumschick)

Effects of land use and seasonal variation on small mammal species of the Magaliesberg Biosphere Reserve. Collaborator: Andre Ganswindt, University of Pretoria (Somers)

EICAT assessment of alien insects in Australia. Collaborators: Melodie McGeoch, Monash University, Melbourne, Australia; Helen Roy, UK Centre for Ecology and Hydrology, UK; Sandy Liebhold, US Forest Service; Lori Lach, James Cooke University; Myron Zalucki, University of Queensland; Manu Saunders, University of New England; David Yeates, CSIRO, ANIC, Australia; Markus Riegler, University of Western Sydney; Treena Burgess, Murdoch University; Andrew Cox, Invasive Species Council, Australia; Sarah Hilton, Department of

Agriculture and Water Resources, Australia; Dave Palmer, Monash University; Carol Booth, Invasive Species Council, Australia; Steven Chown, Monash University; Chris McGrannachan, Monash University; Sandra Parson, Australian Bureau of Agriculture and Resource Economics and Science; Rebecca O'Connor, Monash University (Kumschick)

Environmental Impact Classification for Alien Taxa (EICAT). Collaborators: Tim Blackburn, University College London, London; Tom Evans, University College London, London; Jonathan Jeschke, Ecosystem Research, IGB Leibniz-Institut of Freshwater Ecology and Inland Fisheries, Berlin, Germany.; Sven Bacher, Department of Biology, Unit Ecology and Evolution, University of Fribourg, Switzerland; Piero Genovesi, ISPRA (Institute for Environmental Protection and Research), Italy; Petr Pyšek, Institute of Botany, Academy of Sciences of the Czech Republic and Department of Ecology, Faculty of Science, Charles University in Prague, Czech Republic; Montserrat Vilà, Estación Biológica de Doñana (EBD-CSIC), Sevilla, Spain; John Wilson, SANBI and Centre for Invasion Biology, Stellenbosch University; Kevin Smith, IUCN, Cambridge, UK (Kumschick)

Energy use in Makhanda. Collaborator: Dr Gladman Thondhla, Department of Environmental Science, Rhodes University, South Africa (Ruwanza)

Effects of invasive *Parthenium hysterophorus* on native plant establishment, soil characteristics and soil enzymatic activities as indicators of impacts in Kruger National Park. Collaborators: Dr Ana Novoa, Academy of Sciences of the Czech Republic, Department of Invasion Ecology, Czech Republic; Prof. Stefan Foord, Department of Zoology, University of Venda. (Foxcroft)

Frameworks used in Invasion Science. Collaborators: Prof. S. Bacher, Université de Fribourg; S. Bertolino, Università degli Studi di Torino, Italy; Tim Blackburn, University College London, London; Kelsey Brock; Marc Cadotte, University of Toronto at Scarborough, Canada; Marnie Campbell; Jane Catford; Dr A. Datta, C·I·B, Stellenbosch University; Curt Daehler; Prof. K.J. Esler, C·I·B, Stellenbosch University; Franz Essl ; Dr T. Evans, University College London, London; Dr K. Faulkner, University of Pretoria; Dr L. Foxcroft, C·I·B, SANParks; Dr P. Genovesi, Institute for Environmental Protection and Research (ISPRA); S. Ghosh, University of Free-State; Dr Q. Groom, Meise Botanical Gardens, Belgium; Dr M. Gryzenhout, University of Free-State; Chad Hewitt; Prof. C. Hui, Stellenbosch University; Prof. Philip Hulme, Lincioln University, New Zealand; Prof. I. Kuehn, Martin-Luther University, Germany; Dr S. Kumschick, C·I·B, SANBI; Dr G. Latombe, University of Vienna, Austria; Andrew Liebhold; Julie Lockwood; V. Magagula, University of Free-State; T. Mbobo, SANBI/C·I·B, Stellenbosch University; Prof. J. Measey, C·I·B, Stellenbosch University; Prof. M. McGeoch, School of Biological Sciences, Monash University, Australia; Prof. L. Meyerson, University of Rhode Island; Prof. M. Robertson, C·I·B, University of Pretoria; Dr T.M. Mokotjomela, C·I·B, SANBI; Prof. M. Somers, C·I·B, Mammal Research Institute, University of Pretoria; T. Nelufule, University of Pretoria, SANBI; Dr T. Paap, FABI, University of Pretoria; Dr J. Pergl, Institute of Botany, Academy of Sciences of the Czech Republic; Dr L. Potgieter, University of Toronto at Scarborough, Canada; Dr A. Probert, Université de Fribourg, Switzerland; Prof. P. Pyšek, Institute of Botany, Academy of Sciences of the Czech Republic and Department of Ecology, Faculty of Science, Charles University in Prague, Czech Republic; Dr S. Rahlao, C·I·B, SANBI; Prof. D.M. Richardson, C·I·B, Stellenbosch University; Prof. T.B. Robinson-Smythe, C·I·B,

Stellenbosch University; Prof. H. Roy, NERC Centre for Ecology and Hydrology, U.K.; Greg Ruiz; A. Santini; D. van der Colff, C·I·B, Dr G. Vimercati, Université de Fribourg, Switzerland; L. Volery, Université de Fribourg, Switzerland; Prof. O.L.F. Weyl, C·I·B, SAIAB; Prof. M. Wingfield, CTHC/FABI, University of Pretoria; Dr T. Zengeya, C·I·B, Invasive Species Unit, SANBI; Dr R. Zenni, Universidade Federal de Lavras, Brazil (Wilson)

Functional responses in aquatic ecosystems. Collaborators: Prof. Jaimie Dick, Queens University Belfast, School of Biological Sciences; Prof. Tony Ricciardi, Redpath Museum, McGill University; Prof. Robert Britton, Department of Life and Environmental Sciences Bournemouth University Poole (Weyl)

Functional responses in aquatic ecosystems. Collaborators: Dr R.J. Wassermann, School of Science, Monash University Malaysia; and Mr Ross Cuthbert, School of Biological Sciences, Queens University Belfast (Weyl)

Generic Impact Scoring System. Collaborators: Sven Bacher, Department of Biology, Unit Ecology and Evolution, University of Fribourg, Switzerland; Tom Evans, University College London, London; Zuzana Marková, Institute of Botany, Academy of Sciences of the Czech Republic; Jan Pergl, Institute of Botany, Academy of Sciences of the Czech Republic; Petr Pyšek, Institute of Botany, Academy of Sciences of the Czech Republic and Department of Ecology, Faculty of Science, Charles University in Prague, Czech Republic; Montserrat Vilà, Estación Biológica de Doñana (EBD-CSIC), Sevilla, Spain; and Wolfgang Nentwig, Institute of Ecology and Evolution, University of Bern, Switzerland (Kumschick)

Global strategy for invasive alien trees, a. Collaborators: Giuseppe Brundu (Università di Sassari), Anibal Pauchard (University of Concepción), Petr Pyšek, Jan Pergl (Czech Academy of Sciences, Institute of Botany) (Richardson)

Guidelines for impact scoring. Collaborators: Sven Bacher, Department of Biology, Unit Ecology and Evolution, University of Fribourg, Switzerland ; Lara Volery, Department of Biology, Unit Ecology and Evolution, University of Fribourg, Switzerland (Kumschick)

High altitude monitoring of biological invasions. Collaborators: Dr Ralph Clark, Dr Sandy Steenhuisen, Afromontane Research Unit, Department of Plant Sciences, University of Free State (Qwaqwa campus); and Prof. Aliza Le Roux, Department of Zoology, University of Free State (Qwaqwa campus); and Dr Grant Martin, Rhodes University (Mokotjomela, Richardson).

Horizon scanning in invasion science. Collaborator: Prof. A. Ricciardi, Redpath Museum, McGill University, Montreal, Canada (Richardson)

Humanness of vertebrate biocontrols, 2018-2020. Collaborators: Ben Allen of the University of Southern Queensland; Matthew Hayward, University of Newcastle, Australia (Somers)

iDIV working group sTWIST (Theory and Workflows for Alien and Invasive Species Tracking) (Wilson)

Impacts of alien birds. Collaborators: Tim Blackburn, University College London, London; and Tom Evans, University College London, London (Kumschick)

Impacts of *Opuntia stricta* on soil properties in Kruger National Park. Collaborators: Dr Ana Novoa, Academy of Sciences of the Czech Republic, Department of Invasion Ecology, Czech Republic; Prof. Jaco Le Roux, Department of Biological Sciences, Macquarie University, Australia (Foxcroft)

Invasion Research Social Networks. Collaborator: Dr Nadia Sitas, CSIR, Stellenbosch (Abrahams PhD) (Esler)

Improved food security and biodiversity, 2019. Collaborators: Dr Tutilo Mudumba, Makerere University, Uganda; Prof. Matt Hayward, University of Newcastle, Australia; Lourens Swanepoel, University of Venda (Somers)

Insect low temperature biology. Prof. Vlad Kostal and Dr Petr Simek, Institute of Entomology, Czech Academy of Sciences, Czech Republic; and Prof. Jesper Sorensen, Dept of BioScience, Aarhus University, Aarhus, Denmark; and Prof. Dan Hahn, University of Florida, Florida, USA. (Terblanche)

Insect Microclimate Modelling. Collaborators: Prof. Art Woods, University of Montana (USA), Dr Sylvain Pincebourde, IRBI-CNRS, France. (Terblanche)

Insect thermal biology, climate change and respiratory anatomy. Collaborator: Dr Philipp Lehmann, Stockholm University, Sweden (Terblanche)

Invasion of African clawed frogs in France. Collaborators: Dr Anthony Herrel UMR 7179 C.N.R.S/M.N.H.N. Paris France; Dr Jean Secondi, University of Angers, Department of Biological Sciences, France (Measey)

Invasive alien species management in the Greater Cape Floristic Region. Collaborators: Julia Wood, Chandre Rhoda, Mfundo Tafeni, and Marco Meyer, Biodiversity Management, City of Cape Town Environmental Management Department, City of Cape Town; Jonathan Bell, NCC Environmental Services, Cape Town, South Africa; Nicola van Wilgen, SANParks Cape Research Centre, Steenberg, Cape Town; Dean Impson and Andrew Turner, CapeNature Biodiversity Capabilities Directorate; Louise Stafford, The Nature Conservancy; Kirstin Stephens and John Wilson, South African National Biodiversity Institute, Kirstenbosch Research Centre; Clova Mabin, Save Our Seas Foundation Shark Education Centre.

Invasive fishes. Collaborator: Dr John Hargrove, Eagle Fish Genetics Lab, Idaho Department of Fish and Game, Idaho; and Dr Mathew Campbell, Eagle Fish Genetics Lab, Idaho Department of Fish and Game, Idaho, Collaborator on invasive fishes. (Weyl)

Invasive fruit flies in Europe and globally. Collaborator: Prof. Nikos Papadopoulis, University of Thessaly, Greece (Terblanche)

Invasive terrestrial invertebrates (book chapter). Collaborator: Dr Charlene Janion-Scheepers, Iziko South African Museum Cape Town (Griffiths)

Invasiveness of horticultural cultivars. Collaborators: Prof. Sjirk Geerts (CPUT); Prof. Chris Daniels (CPUT); Mr Terence Mabela (Kumschick, Wilson)

Maintaining functionality of savanna ecosystems in Kruger National Park. Collaborators: Prof. Petr Pyšek, Department of Invasion Ecology, Institute of Botany, Academy of Sciences of the Czech Republic, Průhonice, and Charles University in Prague, Czech Republic (Foxcroft)

Managing fouling on recreational yachts. Collaborator: Dr Kerry Sink, SANBI (Robinson-Smythe)

Metabolic fuel use in ectotherms. Collaborators: Prof. Marshall McCue, Sable Systems, USA (Terblanche, Clusella-Trullas)

Novel detection methods for centrarchid fisheries and impacts. Collaborator: Prof. Nicholas Mandrak, University of Toronto Scarborough, Department of Biological Sciences (Weyl)

Novel detection methods for early invaders and rare species. Collaborators: Prof. Nicholas Mandrak, University of Toronto Scarborough, Department of Biological Sciences; Ms Becky Cudmore, Fisheries and Oceans Canada, Regional Manager, Aquatic Invasive Species Program; and Mr Antonio Pegado, Instituto de Investigacao Pesquera, Moizambique (Weyl)

Opuntia and Tamarix genetics. Collaborator: Dr Kelsey Glennon, Wits, APES (Byrne)

Perceptions of water use by alien trees and other social studies pertaining to invasions. Collaborator: Prof. C. Kull, Institute of Geography and Sustainability, University of Lausanne, Switzerland (Richardson)

Pest biosecurity in sugarcane. Prof. Des Conlong (SASRI), Dirk McGelligott (Zambia Sugar/Illovo). (Terblanche)

Predicting the impacts of climate change on terrestrial insects across Africa. Collaborators: Dr Brent Sinclair, Department of Biology, University of Western Ontario, Canada; and Dr Mhairi McFarlane, The Nature Conservancy of Canada, Canada. (Barton, Terblanche)

Remote Sensing. Collaborator: Dr Elhadi Adam, Wits, GAES (Byrne)

Role of biotic interactions in plant invasions, book on. Collaborator: Prof. A. Traveset, Institut Mediterrani d'Estudis Avançats, Balearic Islands, Spain (Richardson)

Sani Pass ant diversity project. Collaborators Prof. Kate Parr and Dr Tom Bishop, School of Environmental Sciences, University of Liverpool, Liverpool. (Robertson).

Seed dispersal: Bramble. Collaborators: Dr I Rushworth, Ezemvelo KZN Wildlife, Pietermaritzburg; Dr M Tedder, University of KwaZulu-Natal, Pietermaritzburg campus (Downs)

Secondary invasion and weedy native species dominance after clearing invasive alien plants. Collaborators: Dr Mlungele Nsikani, Centre for Invasion Biology and Department of Botany and Zoology, Stellenbosch University, South Africa (Ruwanza)

Small mammal ecology. Collaborator, Prof. Ara Monadjem, Department of Biological Sciences, University of Swaziland (Chimimba)

SnapShot Safari South Africa - Mammal distributions in South Africa, 2018-2020. - Collaborators: Jan Venter, Herve Fritz, Nelson Mandela University; Rob Slotow, Colleen Downs, Sandi Willows-Munro, University of KwaZulu-Natal; Mike Peel, ARC; Mark Keith, University of Pretoria; Craig Packer, University of Minnesota, Craig Tambling, University of Fort Hare; Lourens Swanepoel, University of Venda; Charlene Bissett, SANParks, Dan Parker, University of Mpumalanga (Somers)

Socio-ecological impacts of Lantana invasion in Vhembe biosphere. Collaborators: Dr Tatenda Dalu, Department of Ecology and Resource Management, University of Venda, South Africa (Ruwanza).

Socio-economic Benefits of Ecological Infrastructure (EI). Collaborators: Prof. Niels Fold and Dr Laura Vang Rasmussen, University of Copenhagen, Dep. of Geosciences and Natural Resource Management, Denmark; Prof. Mark New, Prof. Stephanie Midgley, Dr Petra Holden, Dr Nadine Methner, Prof. Sheona Shackleton, University of Cape Town, African Climate and Development Initiative; Dr Alanna Rebelo, University of Stellenbosch, Dep. Conservation Ecology and Entomology; Dr Sabine Stuart-Hill, University of KwaZulu-Natal, Centre for Water Resources Research; Aurecon; DHI South Africa (Esler)

Socio-Economic Impact Classification for alien Taxa (SEICAT): Sven Bacher, Department of Biology, Unit Ecology and Evolution, University of Fribourg, Switzerland ; Lara Volery, Department of Biology, Unit Ecology and Evolution, University of Fribourg, Switzerland; Petr Pyšek, Institute of Botany, Academy of Sciences of the Czech Republic and Department of Ecology, Faculty of Science, Charles University in Prague, Czech Republic; Montserrat Vilà, Estación Biológica de Doñana (EBD-CSIC), Sevilla, Spain; Wolfgang Nentwig, Institute of Ecology and Evolution, University of Bern, Switzerland; Dave Richardson, C·I·B, Stellenbosch University; and John Wilson, SANBI and Centre for Invasion Biology, Stellenbosch University; Piero Genovesi, ISPRA (Institute for Environmental Protection and Research), Italy; Tim Blackburn, University College London, London; Marc Kenis, CABI, Delemont, Switzerland; Wolfgang Rabitsch, Umweltbundesamt, Vienna, Austria; Jonathan Jeschke, Freie Universitaet Berlin, Germany; : Franz Essl, Umweltbundesamt, Vienna, Austria; Jaakko Heikkilä, Natural Resources Institute Finland (Luke), Helsinki, Finland; Glyn Jones, The Food and Environment Research Agency, UK; Reuben Keller, Institute of Environmental Sustainability, Loyola University Chicago, USA; Christoph Kueffer, Institute of Integrative Biology, ETH Zurich, Switzerland; Angeliki F. Martinou, Joint Services Health Unit, Cyprus; Jan Pergl, The Czech Academy of Sciences, Průhonice, Czech Republic; Helen E. Roy, Centre for Ecology and Hydrology, UK; Wolf-Christian Saul, Freie Universitaet Berlin, Germany; Riccardo Scalera, IUCN/SSC Invasive Species Specialist Group, Italy (Kumschick)

Species on the Move conference; post-conference writing workshop held in July 2019 in the Kruger Park, South Africa. Collaborators: conference conveners and committee members, session chairs and keynote speakers. (Clusella-Trullas).

Tamarix. Collaborator: Prof. Glynis Goodman Cron, Wits, APES (Byrne)

Tamarix biocontrol. Collaborators: Dr Tom Dudley, Marine Science Institute, University of California; Dr Dan Bean, Colorado Department of Agriculture; Dr Massimo Cristifaro, Accademia Nazionale Italiana di Entomologia (Byrne)

Tree health in SANBI botanic gardens and monitoring for invasion. Collaborators: Dr Trudy Paap; Dr Mesfin Gossa; Prof. Mike Wingfield, FABI/UP (Wilson)

Tamarix Remote Sensing. Collaborator: Dr Solomon Newete, ARC (Byrne)

Understanding *Echium* invasion and impacts. Collaborators: Dr Candice-Lee Lyons, PPRI, ARC, Stellenbosch; Dr Erika Podest, JPL, NASA, USA (Duncan PhD); Dr Colleen Seymour, Dr James Pryke (Homani MSc) (Esler).

Ungulate invasive seed dispersal. Collaborators: Dr Christopher Baltzinger, National Research Institute of Science and Technology for Environment and Agriculture (IRSTEA), France (Downs)

Woody Weeds in East Africa. Collaborators: Dr Urs Schaffner, CABI Switzerland; Dr Arne Witt, CABI, Nairobi (van Wilgen)

Information brokerage

Popular articles and talks

Articles

Sishuba, S. 2019. Putting plant extinctions in South Africa in perspective. Farmer's Weekly. 20 September 2019.

Talks

Foxcroft, L.C. Reflecting on and learning from the past to shape the future. Grow and Groom 2019, Golden Gate National Park, 12 February 2019.

Karsten, M. and Terblanche, J.S. Some like it hot: winners and losers of climate change. HORTGRO Research Symposium, Somerset West, South Africa, 5 June 2019.

Ruwanza, S. Integrating ecological restoration knowledge into rangeland management. NMU SASUF Workshop on climate change mitigation, adaptation, and benefits of wider rangelands, Port Elizabeth, 6 May 2019.

Shivambu, C.T., Shivambu, N. and Downs, C.T. 2019. Aspects of feeding biology of invasive rose-ringed parakeets *Psittacula krameri* in Durban metropolitan, KwaZulu-Natal Province. CrocWorld Conservation Centre, Scottburgh, 9 November 2019.

Shivambu, N, Shivambu, C.T. and Downs, C.T. 2019. Assessing the potential impacts of exotic small mammals in the South African pet trade. CrocWorld Conservation Centre, Scottburgh, 9 November 2019.

Media interactions

Newspaper articles

79 SA plantspesies sterf uit. Die Burger (Wes-Kaap). 23 Augustus 2019.

Skokkende tempo van plantuitsterwing in SA. Tygerburger (Durbanville). 28 Augustus 2019.

Faber, T. 2019. 79 SA plant species confirmed extinct. Saturday Dispatch (Lifestyle). 24 August 2019.

Le Roux, J. 2019. Earth becomes less biodiverse. The Citizen KZN Saturday. 24 August 2019.

Staff Reporter. 2019. 79 species lost in 3 biodiversity hotspots. Cape Argus Early. 23 August 2019.

Staff Writer. 2019. Study: 79 plants extinct in SA's biodiversity hotspots. Cape Times. 23 August 2019.

Witness Reporter. 2019. Dying rapidly. The Witness. 29 August 2019.

Electronic media

79 plants now extinct in SA biodiversity hotspots. Bizcommunity, [online] August 29, 2019. Available at: <https://www.bizcommunity.com/Article/196/628/194945.html>

African Union honours DST/NRF CoE Director. National Research Foundation, [online] January 29, 2019. Available at: <https://www.nrf.ac.za/tags/kwame-nkrumah-award-scientific-excellence>

African Union recognises world leader in invasion biology with Kwame Nkrumah award. Eureka Alert, [online] February 8, 2019. Available at: <https://www.eurekalert.org/pub_releases/2019-02/su-aur020819.php>

African Union recognizes Forest Ecosystems Board Member Dr Richardson. Forest Ecosystems (Springer), [online]. Available at: <https://forestecosyst.springeropen.com/african-union-recognizes-forest-ecosystems-board-member-dr--rich>

African Union recognizes world leader in invasion biology with Kwame Nkrumah Award. Pan African News Wire, [online] February 9, 2019. Available at: <http://panafricannews.blogspot.com/2019/02/african-union-recognizes-world-leader.html>

ASSAf Members in the News. Academy of Science of South Africa (ASSAf), [online] March 25, 2019. Available at <http://www.assaf.co.za/newsletter/?p=2303>

Be prepared: prioritising invasive species for strategic prevention (Durban, South Africa). Phys.org, [online] June 24, 2019. Available at: <https://phys.org/news/2019-06-prioritising-invasive-species-strategic-durban.html>

Be prepared: prioritising invasive species for strategic prevention (Durban, South Africa). Eureka Alert, [online] June 24, 2019. Available at: <https://www.eurekalert.org/pub_releases/2019-06/pp-bpp062119.php>

Brandt, K. 2019. Some plant species in SA's biodiversity hotspots confirmed extinct. Eyewitness News, [online] 24 August 2019. Available at: <https://ewn.co.za/2019/08/24/some-plant-species-in-sa-s-biodiversity-hotspots-confirmed-extinct>

Clusella-Trullas S. 2019. As climate changes, species – including humans – are on the move! Notes from Species on the Move conference. Functional Ecologists – a Blog for people behind the research. [online] 28 August 2019. Available at: <https://functionalecologists.com/2019/08/28/as-climate-changes-species-including-humans-are-on-the-move-notes-from-species-on-the-move-conference/>

Dapcevich, M. 2019. Plant species in biodiversity hotspots declining up to 350 times faster than historical average. IFLS, [online] 24 August 2010. Available at: <https://www.iflscience.com/environment/plant-species-in-biodiversity-hotspots-declining-up-to-350-times-faster-than-historical-average/>

Extinction crisis – SA is losing plants at an alarming rate. All 4 Women, [online] August 23, 2019. Available at: <https://www.all4women.co.za/1827845/news/south-african-news/extinction-crisis-sa-is-losing-plants-at-an-alarming-rate>

Farber, T. 2019 SA plants being booted into extinction at a staggering rate. Times Live, [online] 23 August 2019. Available at: <https://select.timeslive.co.za/news/2019-08-23-sa-plants-being-booted-into-extinction-at-a-staggering-rate/>

Fourie-Basson, W. 2019. Shocking rate of plant extinctions in South Africa. Science Daily, [online] August 22, 2019. Available at: <https://www.sciencedaily.com/releases/2019/08/190822141918.htm>

Fourie-Basson, W. 2019. Shocking rate of plant extinctions in South Africa. Archaeology News Network, [online] 22 August 2019. Available at: <https://archaeologynewsnetwork.blogspot.com/2019/08/shocking-rate-of-plant-extinctions-in.html>

Getachew, A. 2019. African leaders wrap up summit. Anadolu Agency, [online] 12 February 2019. Available at: <https://www.aa.com.tr/en/africa/african-leaders-wrap-up-summit/1389841>

Goecker, L. 2019. Study: Earth is losing plant species 350 times faster than historical average. The Swaddle, [online] 10 September 2019. Available at: < https://theswaddle.com/plant-extinction-rate-350-times-faster-than-history/>

Hirsch, H. 2019. Plants are going extinct up to 350 times faster than the historical norm. The Conversation, [online] 22 August 2019. Available at: <https://theconversation.com/plants-are-going-extinct-up-to-350-times-faster-than-the-historical-norm-122255>

Hirsch, H. 2019. River red gum in South Africa — towards a national management strategy. Medium, [online] 10 December 2019. Available at: <https://medium.com/@centreinvasionbiology/river-red-gum-in-south-africa-towards-a-national-management-strategy-c347a8f1f6b5>

Hirsch, H. 2019. South Africa needs a fresh approach to managing invasive trees like Eucalyptus. The Conversation, [online] December 29, 2019. Available at: <https://theconversation.com/south-africa-needs-a-fresh-approach-to-managing-invasive-trees-like-eucalyptus-126777>

How research networks can help BRICS countries combat invasive species. Bizcommunity, [online] October 28, 2019. Available at: <https://www.bizcommunity.africa/Article/410/628/197173.html>

Jain, N. 2019. Invasive bullfrog tadpoles devour native ones in the Andamans. India Mondagbay, [online] 13 December 2019. Available at: <https://india.mongabay.com/2019/12/invasive-bullfrog-tadpoles-devour-native-ones-in-the-andamans/>

Khanna, M. 2019. Plants are going extinct 350 times faster than normal, but we just don't seem to care. India Times, [online] 25 August 2019. Available at: <https://www.indiatimes.com/technology/news/plants-are-going-extinct-350-times-faster-than-normal-but-we-just-don-t-seem-to-care-374305.html>

Kruger, N. 2019. Invasive tadpoles can recognise potential predators in new environments. All Africa, [online] 18 September 2019. Available at: <https://allafrica.com/stories/201909180108.html>

Kruger, N. 2019. Invasive tadpoles can recognise potential predators in new environments. The Conversation, [online] September 17, 2019. Available at: < https://theconversation.com/invasive-tadpoles-can-recognise-potential-predators-in-new-environments-119673>

Le Roux, J. 2019. Plants are going extinct up to 350 times faster than the historical norm. BuzzFlash, [online] 30 August 2019. Available at: <https://buzzflash.com/articles/plants-are-going-extinct-up-to-350-times-faster-than-the-historical-norm>

Le Roux, J. 2019. Estamos extinguiendo plantas 350 veces más rápido de lo normal. The Conversation, [online] 31 October 2019. Available at: <https://theconversation.com/estamos-extinguiendo-plantas-350-veces-mas-rapido-de-lo-normal-126156>

Le Roux, J. 2019. Extinction is normal but plants going extinct 350 times faster should alarm us. The Print, [online] 26 August 2019. Available at: <https://theprint.in/environment/extinction-is-normal-but-plants-going-extinct-350-times-faster-should-alarm-us/282028/>

Le Roux, J. 2019. Laju kepunahan tanaman 350 kali lebih cepat akibat kerusakan habitat saat ini. The Conversation [online] 25 September 2019. Available at: <https://theconversation.com/laju-kepunahan-tanaman-350-kali-lebih-cepat-akibat-kerusakan-habitat-saat-ini-124011>

Le Roux, J. 2019. Plants are going extinct 350 times faster than they have historically, experts warn. Daily Mail, [online] 23 August 2019. Available at: <https://www.dailymail.co.uk/sciencetech/article-7388043/Plants-going-extinct-350-TIMES-faster-historically-experts-warn.html>

Le Roux, J. 2019. Plants are going extinct up to 350 times faster than the historical norm. South Africa news, [online] 23 August 2019. Available at: <https://www.southafricanews.net/news/262157774/plants-are-going-extinct-up-to-350-times-faster-than-the-historical-norm>

Le Roux, J. 2019. Plants are going extinct up to 350 times faster than the historical norm. Johannesburg News, [online] 23 August 2019. Available at: <https://www.johannesburgnews.net/news/262157774/plants-are-going-extinct-up-to-350-times-faster-than-the-historical-norm>

Le Roux, J. 2019. Plants are going extinct up to 350 times faster than the historical norm. Quartz Africa, [online] 24 August 2019. Available at: <https://qz.com/africa/1694276/plants-are-going-extinct-350-times-faster-than-normal/>

Le Roux, J. 2019. Plants are going extinct up to 350 times faster than the historical norm. The Village News, [online] 2 September 2019. Available at: <https://thevillagenews.co.za/plants-are-going-extinct-up-to-350-times-faster-than-the-historical-norm/>

Le Roux, J. 2019. Plants are going extinct up to 350 times faster than the historical norm. Phys.org, [online] 23 August 2019. Available at: <https://phys.org/news/2019-08-extinct-faster-historical-norm.html>

Le Roux, J. 2019. Plants are going extinct up to 350 times faster than the historical norm. News24, [online] 25 August 2019. Available at: < https://www.news24.com/Green/News/plants-are-going-extinct-up-to-350-times-faster-than-the-historical-norm-20190825>

Le Roux, J. 2019. Plants are going extinct up to 350 times faster than the historical norm. Kevin's walk on the wildside, [online] 26 August 2019. Available at: <https://kevinswildside.wordpress.com/tag/plants/>

Le Roux, J. 2019. Plants are going extinct up to 350 times faster than the historical norm. Viw Magazine, [online] 23 August 2019. Available at: <http://www.viw.com.au/index.php/21951-plants-are-going-extinct-up-to-350-times-faster-than-the-historical-norm>

Le Roux, J. 2019. Plants becoming extinct up to 350 times faster than historical norm. Power987, [online] 26 August 2019. Available at: <https://www.power987.co.za/comment-and-analysis/plants-becoming-extinct-up-to-350-times-faster-than-historical-norm/>

Le Roux. J. 2019. Plants are going extinct up to 350 times faster than the historical norm. The Conversation, [online] August 22, 2019. Available at: < https://theconversation.com/plants-are-going-extinct-up-to-350-times-faster-than-the-historical-norm-122255>

Leshilo-Sebake, J. 2019. DST proud of South African scientists recognised for their significant research on the continent. Department of Science and Technology, [online]. Available at: <https://www.dst.gov.za/index.php/media-room/latest-news/2746-dst-proud-of-south-african-scientists-recognised-for-their-significant-research-on-the-continent>

Measey, J. 2019. BRICS scientists could help stem the tide of invasive species. The Conversation, [online] November 7, 2019. Available at: <https://theconversation.com/brics-scientists-could-help-stem-the-tide-of-invasive-species-126210>

Mohanty, N. 2019. Global pet trade in amphibians is bigger than we thought. All Africa, [online] 22 October 2019. Available at: <https://allafrica.com/stories/201910230137.html>

Mohanty, N. 2019. Global pet trade in amphibians is bigger than we thought. eNews Channel Africa, [online] 22 October 2019. Available at: <https://www.enca.com/analysis/global-pet-trade-amphibians-bigger-we-thought>

Mohanty, N. 2019. Global pet trade in amphibians is bigger than we thought. Infurmation, [online] 24 October 2019. Available at: <http://www.infurmation.co.za/articles/global-pet-trade-in-amphibians/>

Mohanty, N. 2019. Global pet trade in amphibians is bigger than we thought. The Conversation, [online] October 22, 2019. Available at: < https://theconversation.com/global-pet-trade-in-amphibians-is-bigger-than-we-thought-124710>

Mohanty, N. 2019. Killer tadpoles threaten Andaman archipelago's native frog species. The Conversation, [online] April 11, 2019. Available at: < https://theconversation.com/killer-tadpoles-threaten-andaman-archipelagos-native-frog-species-114845>

Neha, J. 2019. The cannibalistic Indian bullfrog is wreaking havoc in the Andamans. Scroll In, [online] 18 December 2019. Available at: <https://scroll.in/article/946986/the-cannibalistic-indian-bullfrog-is-wreaking-havoc-in-the-andamans>

Pacha, A. 2019. The growing global trade in amphibian pets. The Hindu, [online] 26 October 2019. Available at: <https://www.thehindu.com/sci-tech/science/the-growing-global-trade-in-amphibian-pets/article29807310.ece>

Perinchery, A. 2019. Indian bullfrogs take to invasive behaviour early in Andamans. The Hindu, [online] 20 April 2019. Available at: <https://www.thehindu.com/sci-tech/science/indian-bullfrogs-take-to-invasive-behaviour-early-in-andamans/article26898389.ece>

Petersen, C. 2019. Stellenbosch scientists use social media for amphibian study. Matie Media, [online] 19 March 2019. Available at: <https://www.matiemedia.org/stellenbosch-scientists-use-social-media-for-amphibian-study/>

Research networks can help BRICS countries combat invasive species. Eureka Alert, [online] October 16, 2019. Available at: <https://www.eurekalert.org/pub_releases/2019-10/su-rnc101619.php>

Research networks can help BRICS countries combat invasive species. Phys.org, [online] October 17, 2019. Available at: <https://phys.org/news/2019-10-networks-brics-countries-combat-invasive.html>

Sexton, C. 2019. Plants are vanishing from biodiversity hotspots at a shocking rate. Earth, [online] 3 November 2019. Available at: <https://www.earth.com/news/plants-vanishing-biodiversity-hotspots/>

Shocking rate of plant extinctions in South Africa. Engineering News, [online] August 23, 2019. Available at: <http://m.engineeringnews.co.za/article/shocking-rate-of-plant-extinctions-in-south-africa-2019-08-23/rep_id:4433>

Shocking rate of plant extinctions in South Africa. Environmental News Network, [online] 22 August 2019. Available at: <https://www.enn.com/articles/59353-shocking-rate-of-plant-extinctions-in-south-africa>

Shocking rate of plant extinctions in South Africa. Inside Ecology, [online] 23 August 2019. Available at: <https://insideecology.com/2019/08/23/shocking-rate-of-plant-extinctions-in-south-africa/>

Skokkende tempo van plantuitsterwing in SA. Tygerburger, [online] Augustus 28, 2019. Available at: <https://www.netwerk24.com/ZA/Tygerburger/Nuus/skokkende-tempo-van-plantuitsterwing-in-sa-20190827-2>

Staff reporter. 2019. 79 species lost in 3 of SA's biodiversity hot spots. Cape Argus, [online] 23 Augustus 2019. Available at: <https://www.iol.co.za/capeargus/news/79-species-lost-in-3-of-sas-biodiversity-hot-spots-31165800>

Staff reporter. 2019. Shocking rate of plant extinctions in South Africa. Bolander, [online] 18 September 2019. Available at: <https://www.bolanderlifestyle.co.za/news/shocking-rate-of-plant-extinctions-in-south-africa-33177584>

Staff reporter. 2019. Shocking rate of plant extinctions. Athlone News, [online] 18 September 2019. Available at: <https://www.athlonenews.co.za/news/shocking-rate-of-plant-extinctions-33121257>

Staff writer. 2019. 79 plants extinct in SA's biodiversity hot spots, research shows. Cape Times, [online] 23 August 2019. Available at: <https://www.iol.co.za/capetimes/news/79-plants-extinct-in-sas-biodiversity-hot-spots-research-shows-31169122>

Staff writer. 2019. Clearing alien species on Cape Flats 'could open way for further invasion'. Cape Times, [online] 12 November 2019. Available at: <https://www.iol.co.za/capetimes/news/clearing-alien-species-on-cape-flats-could-open-way-for-further-invasion-37069079>

Staff writer. 2019. Plants are going extinct up to 350 times faster than the historical norm. Down to Earth, [online] 23 August 2019. Available at: <https://www.downtoearth.org.in/news/wildlife-biodiversity/global-eco-watch-major-ecological-happenings-of-the-week-august-19-august-25--66335>

Sthandile, M. 2019. How research networks can help BRICS countries combat invasive species. Social TV, [online] 28 October 2019. Available at: <https://social-tv.co.za/how-research-networks-can-help-brics-countries-combat-invasive-species/>

Wanneer die portjacksons val staan ander indringerspesies op. Eikestadnuus, [online] November 13, 2019. Available at: <https://www.netwerk24.com/ZA/Eikestadnuus/wanneer-die-portjacksons-val-staan-ander-indringerspesies-op-20191113>

Young, C. 2019. Researchers find a new way to strategically prevent species invasions. Interesting Engineering, [online] 28 June 2019. Available at: <https://interestingengineering.com/researchers-find-a-new-way-to-strategically-prevent-species-invasions>

Articles published by Stellenbosch University

African Union recognises SU world leader in invasion biology. SU News, [online] 28 January 2019. Available at: <http://www.sun.ac.za/english/Lists/news/DispForm.aspx?ID=6198>

Afrika-Unie vereer wêreldbekende US indringerbioloog. US Nuus, [aanlyn] 28 Januarie 2019. Beskikbaar by: <http://www.sun.ac.za/afrikaans/Lists/news/DispForm.aspx?ID=6118>

Research networks can help BRICS countries combat invasive species. SU News, [online] 16 October 2019. Available at: < http://www.sun.ac.za/english/Lists/news/DispForm.aspx?ID=6834>

Navorsingsnetwerke kan BRICS-lande help om indringerspesies te beveg. US Nuus, [aanlyn] 16 Oktober 2019. Beskikbaar by: <http://www.sun.ac.za/afrikaans/Lists/news/DispForm.aspx?ID=6754>

Fourie-Basson, W. 2019. Shocking rate of plant extinctions in South Africa. SU News, [online] 22 August 2019. Available at: <http://www.sun.ac.za/english/Lists/news/DispForm.aspx?ID=6666>

Fourie-Basson, W. 2019. Skokkende tempo van plantuitsterwing in Suid-Afrika. US Nuus, [aanlyn] 22 Augustus 2019. Beskikbaar by: <http://www.sun.ac.za/afrikaans/Lists/news/DispForm.aspx?ID=6586>

SU mathematician contributes to mapping global tree-microbe symbioses. SU News, [online] 22 May 2019. Available at: <http://www.sun.ac.za/english/Lists/news/DispForm.aspx?ID=6423>

US wiskundige dra by tot kartering van globale boom-mikrobe-simbiose. US Nuus, [aanlayn] 22 Mei 2019. Beskikbaar by: <http://www.sun.ac.za/afrikaans/Lists/news/DispForm.aspx?ID=6343>

Radio and television

Hirsch, H. 2019. Radio interview on John Maytham Show (Cape Talk) about the rate of biodiversity loss in South Africa's biodiversity hotspots. August 2019. Available at: <http://www.capetalk.co.za/podcasts/144/the-john-maytham-show/240293/plants-are-going-extinct-up-to-350-times-faster-than-the-historical-norm>

Hirsch, H. 2019. Television interview on eNews Channel Africa about the rate of biodiversity loss in South Africa's biodiversity hotspots. August 2019. Available at: <https://www.youtube.com/watch?v=uHdrX35wrZQ&feature=share>

Le Roux, J. 2019. Radio interview on Driesestig (Radio Sonder Grense Plus) about the rate of biodiversity loss in South Africa's biodiversity hotspots. August 2019.

Measey, J. 2019. Radio interview on Smile FM about the need for BRICS countries to work on invasions together. October 2019.

Mohanty, N. 2019. Television interview on eNCA interview about the global trade in amphibians. October 2019. Available at: <https://www.youtube.com/watch?v=wzqOn2Ry3eI&feature=youtu.be>

Nsikani, M. 2019. Radio interview on the John Maytham Show (Cape Talk) on the rise of secondary invaders after the clearing of primary invaders. November 2019. Available at: <http://www.capetalk.co.za/podcasts/144/the-john-maytham-show/263412/when-port-jacksons-fall-other-invasive-species-rise>

Shivambu, N. 2019. Radio interview on Lotus FM about assessing the potential impacts of exotic small mammals in the South African pet trade. November 2019.

Terblanche, J. 2019. Interview on Radio Namibia about research on Lepidoptera response to climate change in Africa. October 2019.

Terblanche, J. 2019. Radio Interview on SmileFM about research on Lepidoptera response to climate change in Africa. October 2019.

Service provision

Panels and committees

International

EICAT Authority: Convener (Kumschick)

Future Earth bioDISCOVERY Core Project, Scientific Committee member. (Weyl)

GEO BON Species Populations Working Group (Wilson)

Global Urban Biological Invasions Consortium (GUBIC) Steering Committee (Richardson)

Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) Global Assessment: Review Editor (Esler)

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). Thematic assessment on Invasive alien species and their control: Lead Author (Foxcroft)

International Ornithological Congress: Fellow (Downs)
Invasive Organism Observation Information Charter: A Task Group of Biodiversity Data Quality Interest Group. Biodiversity Information Standards (TDWG) (Wilson)
Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES); Coordinating Lead Author – Deliverable 3(b)(ii): Thematic global assessment on invasive alien species and their control, Chapter 2 – Global Trends and Status on Invasive Species. www.ipbes.net (Rahlao)
IUCN Species Survival Commission - Afrotheria specialist Group: Member (Downs)
IUCN Species Survival Commission - Crocodile specialist Group: Member (Downs)
IUCN Species Survival Commission - Freshwater Fish Specialist Group, Regional Chair Southern Africa (Weyl)
IUCN Species Survival Commission - Hippo specialist Group: Member (Downs)
IUCN Species Survival Commission - Invasive Species Specialist Group: Member (Foxcroft; Kumschick; Richardson; van Wilgen; Wilson)
IUCN Species Survival Commission - Ladybird specialist group: member (Clusella-Trullas)
IUCN Species Survival Commission - Otter Specialist Group: Member and Southern African Coordinator (Somers)
IUCN Species Survival Commission - Re-introduction specialist Group: Member (Somers)
IUCN Species Survival Commission - Small Carnivore Specialist Group: Member (Somers).
IUCN Species Survival Commission - Southern African Plants Specialist Group (Richardson)
IUCN Species Survival Commission - Specialist Group on Conifers (Richardson)
IUCN Species Survival Commission - Spider and Scorpion Specialist Group (Foord)
IUCN Species Survival Commission - Stork specialist Group: Member (Downs)
IUCN Species Survival Commission - Wild Pig Specialist Group: Member (Somers).
LIFE-CROAA (https://www.life-croaa.eu/en/home/) Commission Européenne dans le cadre du programme européen LIFE: Scientific Committee Member (Measey)
MEDECOS Association, ISOMED, Executive Committee, National Representative (Esler)
Society for Ecological Restoration: Executive committee and Programme Committee, SER 2019 (Esler)

National

Alien Species Risk Analysis Review Panel (ASRARP): member (Kumschick; Ruwanza; Wilson [Chair])
CAPE Invasive Alien Animal Working Group: Member (Davies, Kumschick, Marais, Measey, Wilson)
Fynbos Forum Committee: Member (Esler)
HERS Advisory Board: Outgoing committee member (Esler)
IUCN Wild Dog Advisory Group of South Africa: Member (Somers)
National Red List for Spiders of South Africa (SANBI) (Foord)
Non-Detriment Finding Committee for *Acinonyx jubatus* (SANBI) (Somers)
Polyphagous Shothole Borer Research Network (Richardson)
WRC Reference Group: The use of long-term, large-scale data combined with historic ecological data to support reserve implementation: Member (Esler)
South African Institute for Aquatic Biodiversity: Advisory Board Member (Griffiths)

Editorial and refereeing activities

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

Conservation Biology, Regional Editor Africa (Esler)
Koedoe (Foxcroft)

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 (Kumschick; Le Roux; Richardson; Weyl)
Ecography (Clusella-Trullas)
Ecological Solutions and Evidence (Zengeya)
F1000 (Terblanche)
Forest Ecosystems (Richardson)
Frontiers in Physiology (Terblanche)
Functional Ecology (Clusella-Trullas)
Herpetological Conservation & Biology (Measey)
Ibis (Downs)
Journal of Fish Biology (Weyl)
Koedoe (Somers)
Mammalian Biology (Somers)
NeoBiota (Foxcroft; Richardson; Wilson)
PeerJ (Measey)
Salamandra (Measey)
South African Journal of Science (Chimimba)
Urban Ecosystems (Downs)

Editorial Boards

Acta Chiropterologica, Editorial Board member (Taylor)
African Entomology, Editorial Board member (Terblanche)
Animals, Editorial Board Member (Griffiths)
Cambridge University Press book series: "Conservation Biology" Editorial Board member (Richardson)
Cambridge University Press book series: "Ecology, Biodiversity, and Conservation" Editorial Board member (Richardson)
Conservation Biology, Regional Editor Africa (Esler)
Journal of Thermal Biology, Editorial Board member (Clusella-Trullas; Terblanche)

Koedoe, Editorial Board Member (Foord; Griffiths)
Mammalia, Editorial Board member (Taylor)
Malagasy Nature, Editorial Board member (Taylor)
Nature Conservation Research, Editorial Board member (Somers)
Ostrich, Editorial Board member (Downs)
Zookeys, Editorial Board member (Foord)

Reviewing

For national (SA) journals

African Entomology; *African Journal of Aquatic Science*; *African Journal of Herpetology*; *African Journal of Marine Science*; *African Journal of Wildlife Research*; *African Zoology*; *Bothalia*; *Ostrich*; *South African Geographical Journal*; *South African Journal of Botany*; *South African Journal of Science*; *Transactions of the Royal Society of South Africa*

For international journals

Acta Adriatica; *Acta Zoologica Cracoviensia*; *Acta Ecologia*; *African Journal of Ecology*; *African Zoology*; *American Naturalist*; *Animal Behaviour*; *Animals*; *Aquatic Ecology*; *Aquatic Invasions*; *Arachnology*; *Ambio*; *Auk*; *Auk- Ornithological Advances*; *Austral Ecology*; *Austral Entomology*; *Biological Conservation*; *Biological Control*; *Biological Invasions*; *Biological Journal of the Linnean Society*; *Biology Letters*; *Biological Reviews*; *Botany*; *Bothalia*; *Conservation Biology*; *Crop Protection*; *Current Zoology*; *Diversity and Distributions*; *Ecography*; *Ecological Monographs*; *Ecology and Evolution*; *Ecology Letters*; *Ecosphere*; *Estuarine, Coastal and Shelf Science*; *Entomologia Experimentalis et Applicata*; *European Journal of Forest Research*; *Evolutionary Ecology*; *Fisheries*; *Forest Ecology and Management*; *Freshwater Biology*; *Frontiers in Ecology and the Environment*; *Frontiers in Ecology and Evolution*; *Frontiers in Zoology*; *Global Change Biology*; *Global Ecology and Conservation*; *Hydrobiologia*; *Ibis*; *Integrative Organismal Biology*; *Integrative Zoology*; *Journal of Animal Ecology*; *Journal of Applied Ecology*; *Journal of Arachnology*; *Journal of Arid Environments*; *Journal of Avian Biology*; *Journal of Biogeography*; *Journal of Environmental Management*; *Journal of Experimental Biology*; *Journal of Fish Biology*; *Journal of Herpetology*; *Journal of Insect Physiology*; *Journal of the Marine Biological Association of the United Kingdom*; *Journal of Natural History*; *Journal of the Society for Integrative and Comparative Biology*; *Journal of Thermal Ecology*; *Journal of Thermal Biology*; *Journal of Zoology*; *Journal of Zoology (London)*; *Landscape Ecology*; *Mammalia*; *Marine Biodiversity: Marine Biodiversity Records*; *Marine Biology*; *Marine Pollution Bulletin*; *Mediterranean Botany*; *Nature Ecology & Evolution*; *NeoBiota*; *Ocean and Coastal Management*; *Oecologia*; *Ostrich*; *PeerJ*; *Pest Management Science*; *Plant Ecology & Diversity*; *PLOS ONE*; *Polar Research*; *Proceedings of the Royal Society B*; *Quaternary Science Reviews*; *Restoration Ecology*; *Revista Biologia Tropica*; *Risk Analysis*; *River Research and Applications*; *Science of the Total Environment*; *Scientific African*; *South African Journal of Botany*; *South American Waterbirds*; *and Zootaxa*

Editing of journal special issues

Journal of Environmental Management: Co-editor of special issue on "The human and social dimensions of invasion science and management". [Vol. 229; 18 papers; 2019; https://tinyurl.com/ycxlv2fa] (Richardson; Shackleton)

Grant reviews for external bodies

IUCN Freshwater Section (Weyl)
JRS Biodiversity Foundation (Weyl)
National Geographic Advisory Board Member- CRE Reviewer Circle (Downs)
National Geographic (Somers)
Water Research Commission (Weyl) For international journals

Appointment reviews and committees

King's College London, UK: academic position probation (Wilson)
King Fahd University, Saudi Arabia: Professorial Appointment (Chimimba)
SANBI: Career Ladder for Scientist Moderation Panel (Zengeya)
Stellenbosch University (Associate Professor Appointment (Weyl)
UKZN Assessor for Academic Promotion (Byrne)
University of KwaZulu-Natal, Associate Professor Appointment (Foord)

NRF service provision

NRF rating and proposal reviews

The C·I·B Core team members participated in 13 rating reviews, one (1) proposal review (the focus area was Conservation and Management of Ecosystems and Biodiversity), and one (1) Research Chair application assessment (to a total of 15).

NRF panel and committee service

The C·I·B team sat on NRF panels for two (2) rating applications; one (1) Research Chair Review; and one (1) NRF Project proposal review (for an SA- Flemish Bilateral Agreement).

Appendix 2. Audited financial statements