DSI-NRF Centre of Excellence for Invasion Biology

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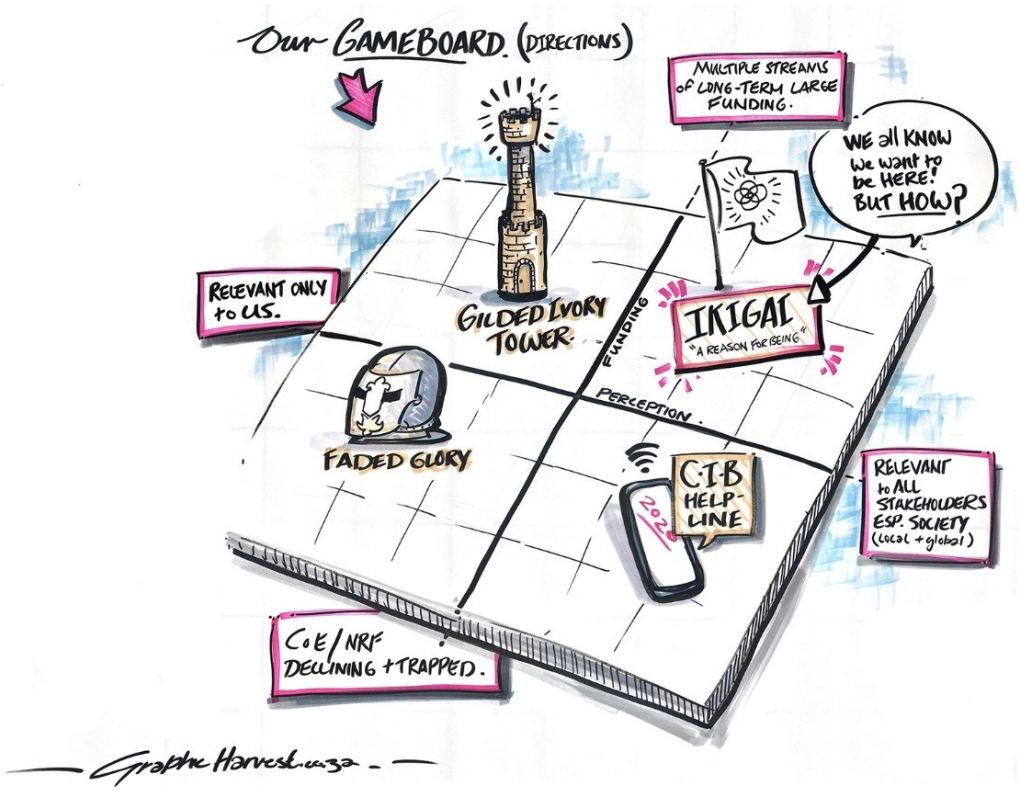
Annual Report
2020



An appreciation - Olaf L.F. Weyl (17 February 1972 – 14 November 2020)

On 14 November 2020 the Centre for Invasion Biology lost one its most valued team members when Olaf Weyl died while doing research on invasive fish near Hogsback in the Eastern Cape.

Olaf was born in Germany but moved to Africa at the age of five. He did his PhD at Rhodes University and then worked in Malawi between 1998 and 2003. Between 2003 and 2009 Olaf was associated with Rhodes University, first as Post-Doctoral Fellow, then as Senior Lecturer. In 2009 he Joined the South African Institute for Aquatic Biodiversity (SAIAB) where he served as Senior Scientist until 2017 when he was award a South African Research Chair in Inland Fisheries and Freshwater Ecology. In 2018 he was appointed Chief Scientist at SAIAB.

Olaf was invited to become a core team member of the Centre for Invasion Biology in 2011 at the suggestion of former SAIAB Director Paul Skelton who served on the Advisory Board of the Centre at the time. Paul enthusiastically informed the Board that Olaf was just the person to head up the freshwater focus in invasion science in South Africa and to build strong links between the C·I·B and SAIAB.

Paul was right! In the decade that he was involved with the C·I·B, Olaf was one of the most productive, most enthusiastic and most highly valued members of the C·I·B core team. He was always available on the phone or via email to discuss problems and opportunities. He always accepted invitations to attend C·I·B meetings and workshops or to provide inputs to reports. At C·I·B annual research meetings (ARMs), Olaf's voice was often heard, asking pressing questions and providing helpful, friendly advice to students. Indeed, one day before he died, Olaf was one of the most active participants in the C·I·B's first ever on-line ARM. His infectious laugh and booming voice was often heard in the passages and during social functions at C·I·B meetings and workshops.

Olaf was author or co-author on 111 journal papers and 5 book chapter that were co-addressed to the C·I·B. He supervised many students and hosted many Post-Doctoral Fellows. He always made it clear that all his team members had two homes: SAIAB and the C·I·B. Olaf was a brilliant academic supervisor and mentor and this was reflected in several of his students being awarded prizes for the best presentations at C·I·B ARMs.

Olaf was deeply committed to the conservation of freshwater ecosystems in Africa and his involvement extended far beyond the corridors, lecture halls and research labs of academia. He participated tirelessly in seemingly endless and stressful meetings aimed at crafting policies for dealing with invasive fishes in South Africa's freshwater systems and the conflicts of interest that often complicate this issue.

Olaf, we thank you for your great contributions to invasion science in South Africa, Africa, and the world. We salute your dedication and commitment. Your work has built a solid foundation for future research and policy development, and alumni from your lab are set to play key roles in invasion science in South Africa and abroad. We will miss you as a colleague and a friend but will cherish our memories of our interactions with you.

Executive summary

Reporting period	:	1 January 2020 - 31 December 2020
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

Preamble

To say that 2020 was a difficult year would be a huge understatement. Covid-19 placed severe restrictions on our operations and necessitated radical changes to how we did business during the year. Despite such an upheaval, a surprising amount of planned work went ahead, much of it via online meetings. Many field-based research projects were severely disrupted. The extent to which C•I•B team members coped with working from home and invented new ways of doing things remains to be fully assessed.

On top of the stresses imposed by Covid-19 the C•I•B was dealt a massive blow on 31 July 2020 when we received notification of a 50% cut in funding for the period 2020-2022. This cut also affected funds already allocated and spent for 2020. This notification overturned the assurance we had received from NRF and DSI in late 2019 and again in March 2020 that funding at 2019 levels was assured for 2020-2022, giving us time to work methodically towards a transition to a new funding model after 2022. A huge amount of time and energy during 2020 was spent dealing with the immediate and short-term repercussions of the funding cut. We were forced to initiate a retrenchment process that eventually led to two staff members leaving the C•I•B. Several other staff members agreed to adjusted terms of employment, and further retrenchments are likely unless new sources of funding are secured early in the year.

Despite the upheavals described above, the 2020 annual report is impressive. The C•I•B remains a world-class centre for the study of biological invasions. However, the writing is on the wall for all to see. Many of the metrics and indicators covered in this document relate to research and other activities that were finished or well advanced before the twin shocks of Covid-19 and the drastic funding cut. This should be borne in mind when assessing performance. Effects of the *annus horribilis* that was 2020 will be more clearly reflected in annual reports of 2021 and beyond.

Progress against Key Performance Areas

Research

The C•I•B's research output in 2020 addressed a wide range of disciplines, scientific approaches, issues, spatial and temporal scales and taxa. We published 183 peer-reviewed papers; these include contributors in top-tier journals such as *BioScience*, *Nature Communications* and *Nature Ecology & Evolution*. Outputs addressed many of the key issues identified as priority areas in our strategic plan. Our research is being applied in management and planning and the C•I•B address appeared on publications that are contributing to advances in many aspects of invasion science globally. Highlights for 2020 were the publication of an open-access book on "Biological invasions in South Africa" and a large special issue of the journal *NeoBiota* on "Frameworks used in invasion science" comprising 24 papers (20 of them with C·I·B-affiliated authors). The open-access book, with contributions from 108 authors (many of them current C·I·B team members or alumni), authoring 31 chapters, provides an encyclopaedic overview of all that is known about biological invasions in South Africa. This book reinforces South Africa's standing as a global leader in invasion science and provides a solid foundation for ongoing work to address the escalating challenges that the country faces from invasive species.

Education and Training

The C•I•B supported 64 students and seven Post-Doctoral Fellows during 2020. Our students continue to be in demand for positions in academic institutions and partner organizations.

Networking

Opportunities for networking were extremely limited in 2020 due to Covid-19. Despite this, many C•I•B team members participated in online gatherings. Of special note here is the important role that is being played by the C•I•B in the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) assessment on alien and invasive species. This assessment, scheduled for completion in 2022, is destined to be another milestone in invasion science.

Information Brokerage

No workshops or symposia were convened in 2020 other than the extensive consultation of our team and partners on the future strategy of the Centre that took place from March to August.

Service Provision

The C•I•B made key contributions to (1) the second National Status Report on Biological Invasions; (2) EICAT protocols, now adopted by the UICN as a standard for impact assessment and (3) The Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES).

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

Women are well represented on the C•I•B's core team and associates and our Stellenbosch hub staff and the Iimbovane team are 100% female. The bulk of the graduates and supported students in 2020 were women.

Red Flags

Securing funding to ensure that the C•I•B can continue operations after 2022 is the top priority for 2022. Given the dire financial situation in South Africa and globally, this is a major challenge.

The dramatic drop in student numbers for 2021, largely as a result of the new NRF student bursary system is worrying. Partnerships will need to be formed with national and international partners to support research and student training to prevent a precipitous decline in our student output.

The leadership vacuum in science policy and management in South Africa is astounding and is hugely worrying. A situation where priorities for investment in science are driven by factors other than the information needs of the country and the pursuit of excellence are destined to erode the country's global standing in science and undermine the role of science as a key contributor to innovation and sustainability.

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. Work also explores how interactions among other global change drivers, especially climate change, potentially exacerbate the impacts of biological invasions.

Projects and integrated programmes of research address all aspects of the phenomenon of biological invasions, all taxonomic and functional groups and all ecosystems, and have 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 skills, tools, insights and types of study. The C·I·B undertakes work under several overarching themes: Biological foundations, model taxa and model systems, detection, elucidation and quantifying impacts; risk assessment; monitoring the development of indicators; restoration; global environmental change and ecosystem services; and the human dimensions of biological invasions. This suite of themes provides the scope for cutting-edge work in invasion science, and the C·I·B is recognized as a global leader in this field. It also provides opportunities to draw in students from diverse biological fields (from fundamental to applied) and many other disciplines. Further details of many research projects are available on the C•I•B's web site (http://academic.sun.ac.za/cib/).

1.2 Progress

The projects summarized below provide a flavour of the wide range of disciplines, taxa, spatial and temporal scales, and scientific approaches in the C•I•B's research during 2020. Research reported here addressed some of the most pressing issues in invasion ecology and the full spectrum of focus areas identified in the C•I•B's strategic plan. Research outputs for 2020 included major reviews, perspectives and "ideas" papers, and original research, most of which draws on the unique opportunities provided by South Africa's wide range of environmental conditions, its rich biodiversity, increasingly pervasive problems with biological invasions, and a complex socio-economic environment.

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

Recognizing the significance of the foundational aspects of biology and the social sciences within invasion science, and the fact that human impacts on natural processes can often not be clearly detected, the C•I•B has undertaken much foundational work over its lifespan. Such work has been crucial for drawing in

students and collaborators who are particularly interested in ‘the workings of nature’ rather than on particular framings of biological invasions.

1.3.1 The importance of life history in invasion science

A paper by recent C•I•B PhD graduate Dr Lubabalo Mofu and co-workers (Mofu *et al*. 2020; J Fish Biol. **97**, 1600–1606) examined the life history of a native fish, the river goby (*Glossogobius callidus*), in irrigation ponds of the Sundays River Valley. The research project aimed to describe the characteristics of this widespread generalist fish species which has several relatives (members of the same fish family Gobiidae) that are invasive in Australia, Europe and North America. Although the invasive relatives are not South African species and did not originate from South Africa, studying the life histories of native fish is important because it provides a window through which researchers can analyse and predict the invasiveness of our native species. Another recent C·I·B publication by Prof. John Measey and collaborators (Measey *et al.* 2020; South Africa as a Donor of Alien Animals, in Van Wilgen et al. (eds) *Biological Invasions in South Africa*, Springer. 787-830) showed that South Africa has been a net recipient of invasive animal species (it has received more invasive species than it has ‘donated’ to other countries), it has been the source of three very significant invasions globally. Interestingly, two of the three important invaders are freshwater species. Mozambique Tilapia, *Oreochromis mossambicus* native to east flowing rivers in central and southern Africa, is now invasive in many different tropical and sub-tropical freshwater and estuarine niches across the world. The African Clawed Frog, *Xenopus laevis*, is perhaps South Africa’s best known invasive species elsewhere and is invasive on all continents except Antarctica. These frogs are widely traded for their usefulness as model animals for lab studies and biomedical tests and often escape from captivity. Mozambique Tilapia are mostly moved around for food and as a result they are very likely to be released into the wild.

Although South African river gobies are not widely traded by aquarists or as pets, they do share some of the characteristics of invasive gobies on other continents. For example, they eat a generalist diet so they are seldom limited by the types of food available; they are also excellent colonisers of new habitats, and readily move into newly constructed dams and impoundments. Dr Mofu and his colleagues found that river gobies mature early (in their second year of life) and although they grow quite slowly (sexually mature fish can be quite small), they are long-lived, as mature wild fish can be up to 7 years old. The researchers discovered the ages of the fish by dissecting their ear bones (otoliths) and counting annual markings to decipher their longevity. The characteristics the researchers identified in river gobies match the characteristics of other invasive fish, and indicate that river gobies may have potential to become invasive elsewhere. Like many other native species that readily colonise human-made

dams and impoundments, their distributions and population numbers may increase in the Anthropocene.

Figure 1. Sample prepared from the otolith of a river goby showing five annual rings (marked by black circles) indicating a five year old individual. [Mofu et al. 2020; *J Fish Biol.* 97, 1600–1606]

1.4 Model systems for understanding invasions and their impacts

Several key groups of organisms and settings/contexts (including Australian acacias, the harlequin ladybird, black bass, African clawed frogs and environments such as urban areas and agricultural contexts) were 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 2020, work was undertaken on aspects of acacias, ladybirds, black bass and African clawed frogs. Some aspects of this work are summarized below.

1.4.1 Acacias as a model system for understanding invasions and impacts

Invasive Australian *Acacia* species (wattles) have commercial and other benefits in some contexts, but major negative impacts in others. They also have substantial influence (positive and negative, depending on geographical and socio-political context) on ecosystem services. Introductions and plantings of wattles in South Africa and elsewhere have created a valuable natural experiment for elucidating many key aspects of invasions science. Wattles have featured prominently in research undertaken at the C·I·B since its inception, and they featured prominently in the C·I·B's research output again in 2020.

Unscrambling the egg: resolving the introduction history for silver wattle

Research at C·I·B has revealed that the introduction histories of the globally important invasive tree silver wattle (*Acacia dealbata*) in different parts of the world are complex and cannot be generalized. This was the finding of a recent molecular study undertaken by C·I·B Post-Doctoral Fellow Heidi Hirsch, C·I·B Director Dave Richardson, former C·I·B Core Team Member Jaco Le Roux, and Anibal Pauchard from the University of Concepción (Chile). Their work sought to unravel the introduction history of silver wattle using genetic fingerprinting.

Genetic fingerprinting methods are often the only way to determine the native origin of invasive species. These methods compare the DNA characteristics between different populations to determine how related they are to each other. An invasive population would show a closer genetic relationship with its native source population than to other native, non-source, populations of the species.

Silver wattle, which is native to eastern and south-eastern parts of Australia and Tasmania, is a widespread and globally important invasive tree. The species is invasive in Chile, La Réunion island, Madagascar, New Zealand, Portugal, and South Africa, where it causes multiple impacts, including changes in soil characteristics, displacement of native plant species, alteration of fire regimes, and depletion of water sources.

The researchers compared the genetic characteristics between populations sampled across the species' native range and in the invasive ranges mentioned above to determine the most likely native source region of invasive silver wattle populations (Hirsch *et al*. 2020; *Diversity Distrib.* **27**, 360-376). For this, the researchers sampled leaf material from which DNA was extracted. In total, 1615 individuals representing 92 populations were sampled from the silver wattle's native and invasive ranges (Figure 2).

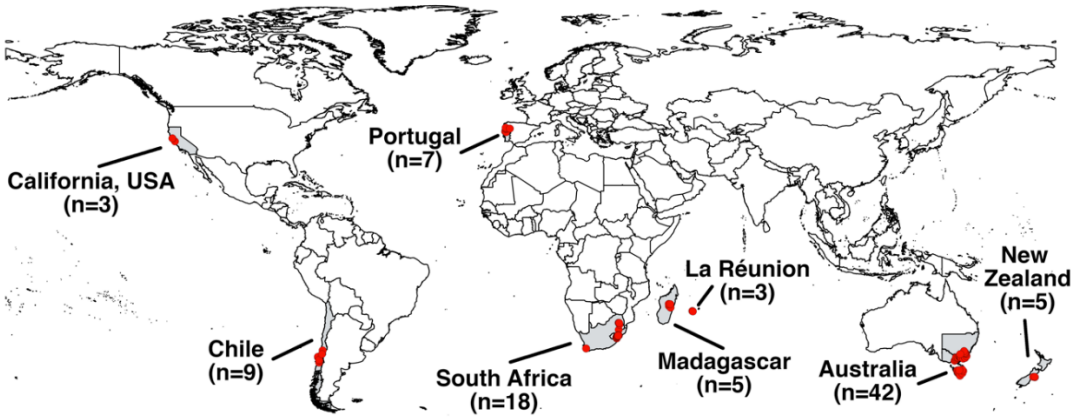


Figure 2. Regions where *Acacia dealbata* samples were collected for genetic fingerprinting. Red circles indicate exact sampling locations and numbers in parentheses give the number of individual populations sampled in each country/region [Hirsch *et al*. 2020; *Diversity Distrib.* 27,360-376].

They found that invasive populations in the different countries do not necessarily share the same native origin. Even the number of introduction events differs between countries. Populations in Chile and Madagascar seem to originate from multiple introductions, followed by genetic admixture between the different sources. Populations in New Zealand and La Réunion, on the other hand, seem to have originated only from Tasmania.

For populations in South Africa, Portugal and the United States, however, the native origin remains unknown. This could be due to a lack of sampling effort in the native range of the species. However, the authors argue that this is unlikely to be the reason, because comprehensive sampling was done across the full native range of silver wattle. An alternative explanation could be that these invasive populations might have been introduced from other source populations, possibly from other parts of the invasive range or from cultivated populations which were not sampled in this study.

The findings highlight that sometimes it is not enough to study an invasive species in only one part of its invasive range if one needs to understand the global invasion history. Country-specific introduction histories of an invasive species add layers of complexity, and these need to be addressed appropriately when developing management strategies.

“Our results,” says Heidi Hirsch, “show that invasive species can have very complex introduction histories; in some cases it is difficult to resolve this complexity even by using highly sophisticated research methods.” She adds, “Since the source of introduction still remains unknown for some of the investigated invasive populations of silver wattle, the next step will be to apply genetic fingerprinting to samples from commercially distributed seeds. This will help us not only to gain a more comprehensive understanding on the species’ global invasion history, but also to find the missing historical link regarding its introduction in South Africa.”

Acacia-released phytochemicals help invasive and native species establishment

Over the past decade much research has been done with the aim of improving our understanding the role of phytochemicals in the success of plant invasions. This research has led to the formulation of the well-known Novel Weapon Hypothesis, which suggests that the release of certain phytochemicals by alien

plants can inhibit the early development of native species that have not previously experienced them, thus granting alien species a competitive advantage. Yet, in native communities, such chemicals help to shape the co-existence of plant species that share evolutionary histories, either by signalling competition avoidance or the presence of suitable conditions. This is in line with another hypothesis - the Biochemical Recognition Hypothesis.

Though the focus of most studies to date has been on investigating the negative impacts of phytochemicals released by invasive species on native plants, work at the C·I·B explored the notion that these chemicals may also have stimulating effects on the establishment of invasive species.

Using an experimental approach the study, led by former C·I·B Post-Doctoral Fellow Florencia Yannelli, examined the effect that phytochemicals released by invasive Australian acacias and native species had on the germination and early growth of both native and invasive species. To do so, researchers from Spain and South Africa, including former C•I•B Core Team Member Jaco Le Roux, former C·I·B Post-Doctoral Fellow Ana Novoa and former C·I·B visiting PhD student Jonatan Rodríguez, collected the phytochemicals released by leaves and flowers of the selected plants.

The researchers tested the effects of these chemicals on the germination and early growth of alien and native species (Figure 3). Contrary to most studies to date, these researchers were not only interested in the detrimental effects of acacia-released phytochemicals on natives, but also how they affected other invasive acacias. Their results revealed that acacia phytochemicals mostly had a stimulating effect on the germination and early growth of the same or other invasive *Acacia* species. These effects were independent of whether acacias shared evolutionary history in their native range or not.

Interestingly, the study also found that phytochemicals collected from native plants in uninvaded areas in South Africa stimulated the germination of the native sweet thorn (*Vachellia karroo*) and the invasive Port Jackson Willow (*Acacia saligna*). While this outcome supports the Biochemical Recognition Hypothesis, the experiments provided no support for the Novel Weapons Hypothesis.

The study suggests that invasive acacias experience phytochemically-induced cues that signal suitable conditions for emergence, and that this ultimately facilitates the invasion process. Such cues can play a role in assuring the success of alien species under harsh environmental conditions, where plants depend on facilitating species or the right conditions for species to emerge.

"This is the only study so far to provide evidence for the stimulatory effects of phytochemicals released by acacias and the role they may have in aiding invasion success of congeneric species. Such aspects have rarely been studied in invasion ecology," said Florencia. "We hope that this work will pave the way for future experiments to test these effects under field conditions, to understand how important they are when acting in concert with other effects of invasions".

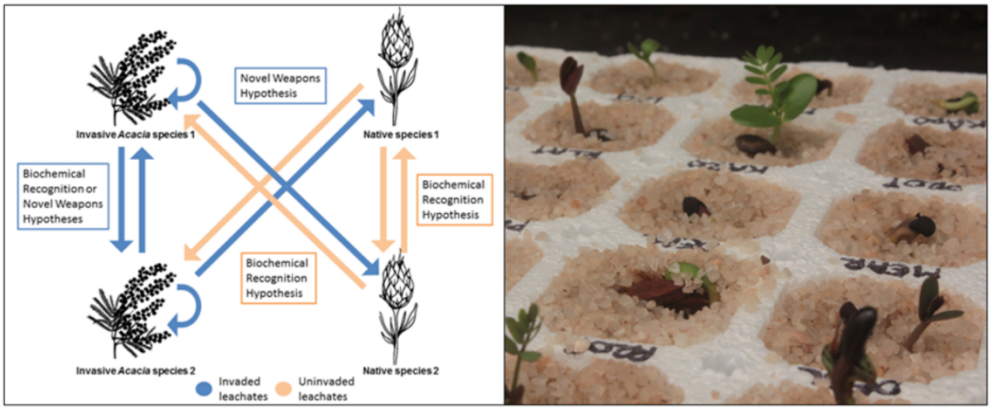


Figure 3. A schematic representation of the hypotheses on how phytochemicals from in plant leachates potentially affect the same or other species. The image on the right shows the growth experiment carried out with South African native and invasive species [Yannelli *et al*. 2020; *Biol. Invasions* 22, 549-562].

1.4.2 Ladybirds

Do early life experiences influence adult performance and fitness in invasive ladybirds?

Like humans training for a marathon run, prior conditioning dramatically influences the probability of success during an extreme athletic event. Invasive insect species have similar challenges in the environments that they occupy or explore, wherein the environmental conditions that they experience during development can have a massive influence on their abilities to secure resources or produce offspring in later life. As with humans, the type, amount and timing of the training or prior experience, can further influence the outcomes at a later stage. Such questions are however poorly explored for invasive insects, despite the valuable insights that these may provide. In particular, such information can improve predictive species distribution modelling and on-going management practices.

C·I·B Master's student Rebecca Shinner, working with C·I·B Core Team Member Susana Clusella-Trullas, tested experimentally whether the globally invasive ladybird beetle *Harmonia axyridis* had performance and survival characteristics that were set and inflexible through life stages, or whether they

were readily adjusted depending on their developmental rearing environmental conditions. By rearing hundreds of beetles in the lab in controlled climate chambers and tracking each parent's traits and offspring production, Rebecca examined whether a short-term exposure to cold, medium or warm fluctuating temperature regimes during larval or adult development affected adult performance, thermal tolerance and fitness of *Harmonia axyridis*. The team found plastic responses of a metric of heat stress resistance—critical thermal maximum—and of preferred body temperature after adult temperature exposure, but not in other traits measured (Shinner *et al*. 2020; *Evolut. Ecol*. **34**, 555-572) (Figure 4). By contrast, exposure of larval stages to varying thermal regimes resulted in plasticity of adult walking performance (height and breadth of the curve) but not tolerance or preference. The work also showed distinct fitness responses between larval and adult treatments, but a composite fitness index revealed negligible effects on reproductive output.

This study demonstrated that different characteristics of *H. axyridis's* performance and ability to cope with extremes respond in diverse ways. For example, the results suggest that the drivers underlying the plasticity of temperature tolerance and temperature selection are different to those shaping the plasticity of walking speed. By testing specific predictions based on current theory of developmental and reversible plasticity, this study contributes novel data to plastic responses of behaviour, stress resistance and fitness to temperature exposure across life stages. Therefore, this study provides insights into the broader evolutionary and ecological significance of these kinds of responses. This information will be used to inform management recommendation of the likely impacts of seasonality on population dynamics of *H. axyridis* and can further be integrated into species distribution modelling. The information generated by this work can be used to better predict the potential impacts of this invasive species on native fauna in South Africa.

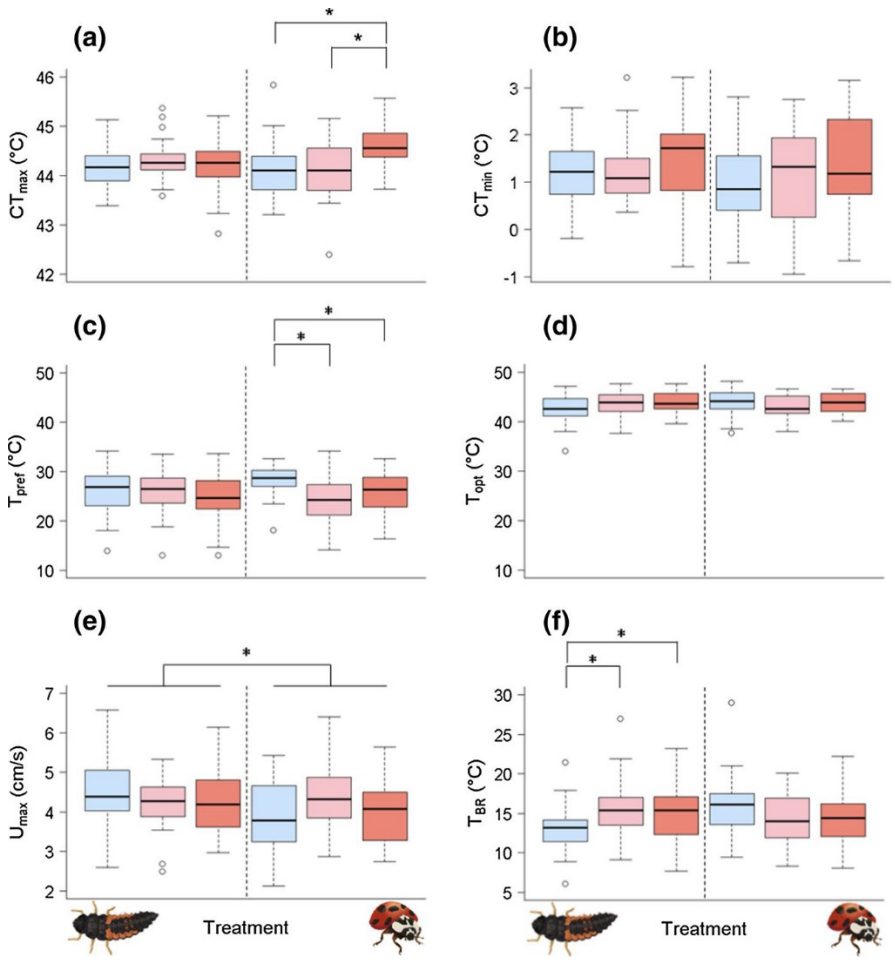


Figure 4. Effects of exposure of larvae and adults of *Harmonia axyridis* to cold, medium and warm temperature treatments on various response metrics [Shinner, R. *et al*. (2020). *Evol. Ecol.* 34, 555-572].

1.4.3 Black bass (Micropterus species)

Micropterus is a genus of nine freshwater fish species that are collectively known as black bass. Four non-native species occur in South Africa: *M. dolomieu*, *M. floridanus*, *M. punctulatus* and *M. salmoides*. *Micropterus salmoides* is the most widespread, and is listed among the 100 of the world's worst invasive species with invasions documented in North and South America, Europe, Africa and Asia. The C·I·B has done extensive research on diverse aspects of the ecology and impacts of black bass. Among the projects undertaken in 2020 was a study of the feeding habitats of *M. salmoides*. Such information is needed to understand the impacts of this invader on native fish species.

All the better to eat you with

The morphological traits of invasive largemouth bass (*Micropterus salmoides*) are more specialised for preying on fish than is the case in other native species. This

was the finding of a collaborative project involving researchers Josie South (Post-Doctoral Fellow), Mhairi Alexander (research associate), C·I·B alumnus Bruce Ellender and core team member Olaf Weyl and colleagues from the University of Wageningen in the Netherlands. Largemouth bass are a global invader and provides a model for studying the context dependency of invasions. Largemouth bass is an efficient fish predator and is known to have negative effects on native species. In most cases, the trophically similar native species Cape kurper (*Sandelia capensis*) have disappeared from stream reaches invaded by largemouth bass. To understand why largemouth bass are capable of having strong consumptive and non-consumptive effects on native species, the project team compared the morphology of juvenile largemouth bass with the trophically similar native species Cape kurper. Morphology is the study of the form of living organisms. The form (internal and external) are directly related to the ecological role of a species and the food it is able to consume.

Results from the morphological analysis shows that largemouth bass are more specialised for pursuit hunting fish prey than Cape kurper, which is more specialised for ambush hunting fish prey (Figure 5). According to C•I•B Post-Doctoral Fellow Josie South and co-author of the paper, this may explain why largemouth bass exert higher impacts on native fish populations than the native species. She adds, “Our results also suggest that Cape kurper are better able to hunt in more complex habitats whereas largemouth bass are not. This means that streams which have degraded habitats could experience higher negative effects from largemouth bass invasions.

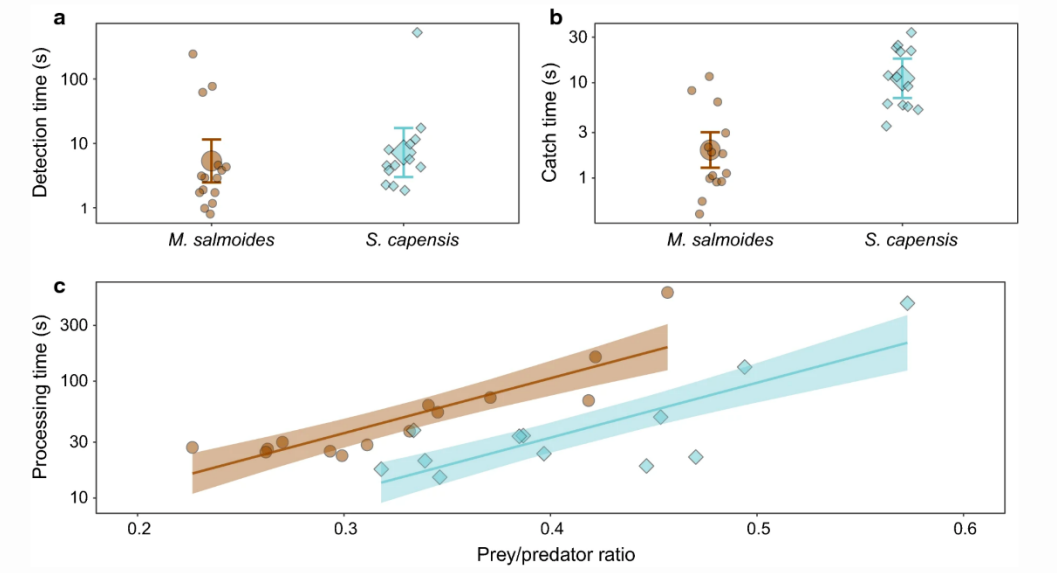


Figure 5. a) Overall geometric mean and 95% confidence interval of detection time; b) Geometric mean and 95%-confidence interval of catch time; c) Processing time in relation to prey/predator size ratio with 95%-confidence intervals. Individual values for *Micropterus salmoides*

indicated by brown circles, and for *Sandelia capensis* by blue diamonds [Luger *et al*. (2020); *Biol. Invasions* 22, 2223–2233].

The African clawed frog - a globally significant invasive amphibian

To accurately model the potential distribution of expanding populations of ectothermic invasive species, we need robust models that determine how the invaders perform in different thermal environments. The model amphibian, the African clawed frog (*Xenopus laevis*), has been the subject of many studies on thermal preferences of laboratory bred populations. Such information is potentially valuable for parametrizing species distribution models, assuming that laboratory-bred animals have not adapted from the wild-type, and that introduced populations themselves have not undergone thermal adaptation. These are big assumptions.

C•I•B PhD student, Laurie Araspin and colleagues (2020) used populations of clawed frogs from two sites in their native range in South Africa and from the invasive range in France to test whether any adaptation had occurred in thermal performance in the ~40 years since their introduction. Surprisingly, French invasive frogs showed a significant rapid shift in their thermal dependence of locomotor performance, implying that they perform better than wild-caught animals at colder temperatures (Figure 6).

This finding shows that the population of invasive frogs currently undergoing expansion in France is better equipped to penetrate more temperate European climates than are individuals from South Africa. This means that distribution models using data from the distribution of wild-caught animals will need to be recalculated to determine just how widespread invasive populations may become.

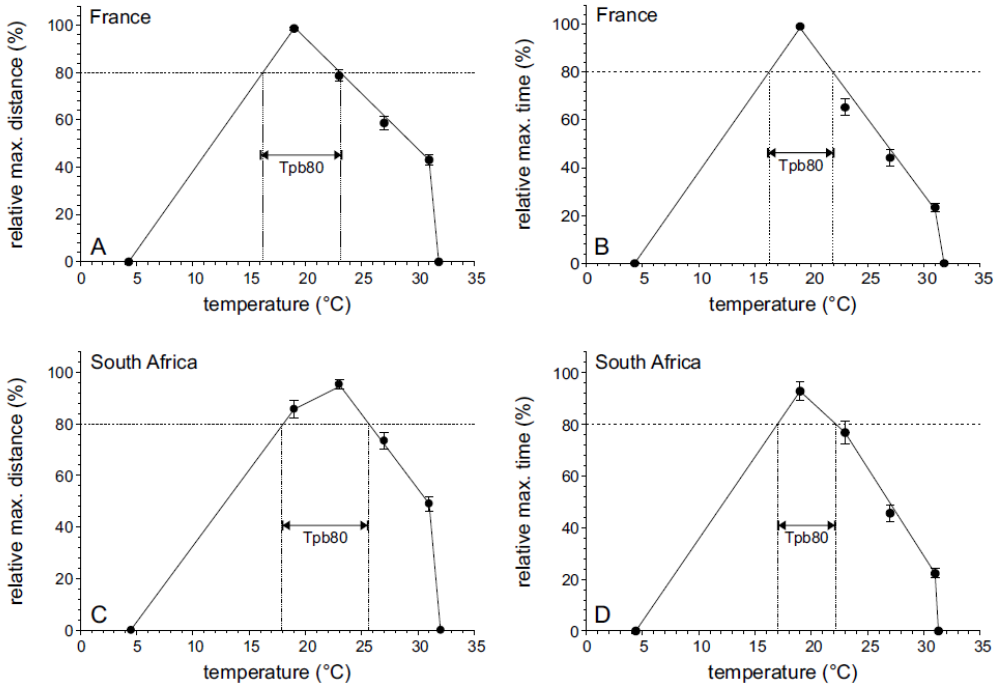


Figure 6. Temperature performance curves illustrating the effect of temperature on endurance capacity in terms of distance (A,C) and time (B,D) for *Xenopus laevis* from France (A,B) and South Africa (C,D)[Araspin *et al*. 2020; *Integr. Comp. Biol*. 60, 456-466]

Agricultural pest insects as models for invasion

Agricultural pest insects present a major challenge to sustainable agriculture and food security in Africa, especially given concerns for their potentially increased threat with climate change. As vectors of plant and animal diseases, direct damage caused by pest feeding and subsequent loss of market value, or indirect economic damage resulting from new or existing international commercial trade barriers, insects pose a multitude of threats to agricultural productivity in South Africa. Pest insects are also often highly polyphagous and affect several commercial crops simultaneously (Pieterse *et al.* 2020; *Bull. Entomol. Res*. **110**, 185-194). Typically pest insects serve as an excellent model system for understanding terrestrial insect invasions as they occur in well-monitored areas with strong infrastructural and logistic support.

While trends suggest that insect abundances are decreasing, problems with pest insects are increasing. It is not straightforward to predict future damage of pest insects in the face of climate change and other global change drivers. An international group including researchers from Stockholm University and Stellenbosch University studied 30 of the most economically-damaging global insect pests. They found a diverse array of responses to climate change (Lehmann *et al*. 2020; *Front. Ecol. Environ*. **18**, 141-150).

That climate is warming globally and locally is undisputed, and a common fear is that warming climates will lead to more damage from insects on plants (Kalinkat *et al*. 2020; Science e-letter. http://science.sciencemag.org/content/361/6405/916/tab-e-letters). For example, the area of deforested Artic birch in northern Scandinavia has increased significantly during the last decades, partly due to the increasing winter survival and range expansion of two moth species, the winter moth (*Operopthera brumata*) and the autumn moth (*Epirrita autumnata*).

Recent research by an international team that included C•I•B Core Team Member John Terblanche showed that for 30 of the globally most detrimental pest insects plant, crop or tree damage also increased, as expected. These include the European spruce bark beetle (*Ips typographus*) and the Russian wheat aphid (*Rhopalosiphum padi*) (Lehmann *et al*. 2020; *Front. Ecol. Environ*. **18**, 141-150). Surprisingly, for over half the species the researchers could find examples of both increased and decreased damage, but in different part of the species range. This is seen for instance in the hemlock woolly adelgid (*Adelges tsugae*) where damage is increasing in the northern part of the range, but decreasing in the southern parts of the range.

These results led C•I•B Fellow Philipp Lehmann and co-workers to conclude that it is difficult to make simple predictions and draw general conclusions about future damage in agricultural and forest ecosystems. They proposed several reasons for the mixed results of their assessment – increasing temperature leads to both increased and decreased damage for certain insect species. One reason could be that the species in some parts of their range already experience such high temperatures that further warming yields no additional positive effects (Figure 7). By contrast, even higher temperatures can lead to negative effects. This is why the distribution of several species is contracting at southern, already warm, latitudes.

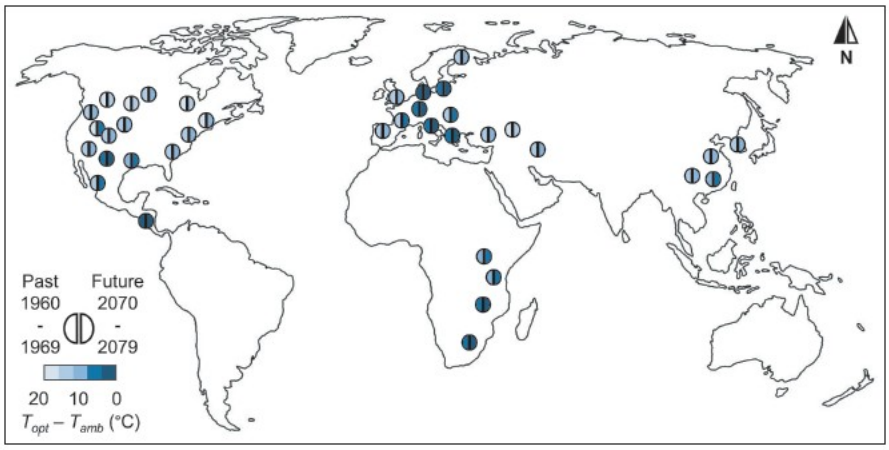


Figure 7. The number of degrees (°C) by which ambient temperature T_{amb} differs from optimal temperature (T_{opt}) in the past (left half of circle) and future (right half of the circle) climates for populations of the pest species included in our analysis. Darker colours represent closer matches between T_{amb} and T_{opt}. Note the general paucity of studies from Africa and the strong Northern Hemisphere bias in data availability (Lehmann *et al*. 2020; *Front. Ecol. Environ*. 18, 141-150).

Another reason could be that the food plants of the pest insects, or their natural enemies, also are affected by warming temperatures. Warming conditions might benefit the host plant but not the herbivore, and vice versa. For example, pest insects can be severely negatively affected by warming temperatures if their natural enemies – often predatory insects – gain more from climate warming.

The variation in responses of pest insects to warming climates, both among and within species, also sheds light on increases and decreases in non-pest insect populations across the globe. That many insects – for instance several species of butterflies – have become spectacularly abundant in Europe lately is at odds with the general dystopic trend painted for the future of insects. To make more realistic predictions one has to account for where, when and how the information was collected, and avoid direct extrapolation of conclusions to other geographic areas and species. Spatially explicit risk models are urgently required for diverse taxa.

The researchers argue that it is difficult to make generalizations on how insects respond to climate change. To make good predictions individual species need to be studied – or at the very least researchers should try to find good representatives for different insect groups with long term monitoring - and test climate-related predictions with robust population dynamic models to infer likely future impacts.

1.5 Detection, elucidation and quantification of impacts and risk analysis

1.5.1 Satellite solutions: Can remote sensing improve our understanding of alien plant distributions?

Invasive alien plants (IAPs) pose major threats to South Africa’s biodiversity, ecosystems and water resources. The availability of moderate-resolution satellite data offers invasion scientists an opportunity to map and monitor the spread of IAPs, thanks to technological advances in satellite remote sensors. Bhongolethu Mtengwana, a C•I•B-funded Masters student at the University of the Western Cape, used two multispectral remote sensing data sets to map IAPs on the Agulhas Plain in the Western Cape. Results from the study showed that satellite

technologies such as Landsat 8 and Sentinel 2 provided an invaluable operational framework for identifying and monitoring the occurrence and distribution of IAPs in catchments and other areas of economic importance.

Advances such as the presence of red-edge and near infrared spectral bands were critical in capturing the inherent and subtle IAPs and other co-occurring plant phenological distinctions (seasonal events such as flowering, changes in leaf colouring), which enhanced their detection and mapping with an acceptable overall accuracy ranging between 70 – 90% (Figure 8). The study showed that IAPs are more pronounced on hill slopes and in riparian zones in the catchment.

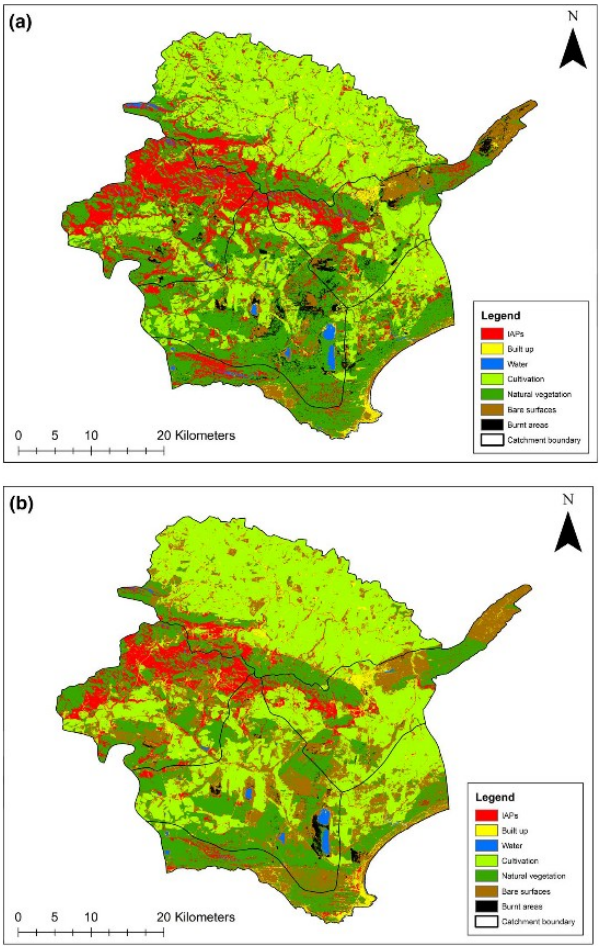


Figure 8. Landsat 8 (a) and Sentinel-2 (b) classified images showing discrimination of invasive alien plants (IAPs) from other land cover classes (Mtengwana *et al*. 2020; *Afr. J. Ecol*. 58, 709-718).

“Our study highlights the value of spatially explicit analytical techniques for monitoring invasive plants, especially in the face of climate change. Satellite remote sensing data presents us with an opportunity to monitor the spread of these species and to mitigate the impacts associated with their spread,” explains Bhongolethu. “Satellite-derived IAPs thematic maps provide a baseline

information for guiding clearing and rehabilitation strategies such as the Working for Water Programme. However, further scientific inquiry is required by considering species-specific potential distribution and more ecologically meaningful remotely sensed derived variables as opposed to raw spectral bands".

1.6 Monitoring and the development of indicators

1.6.1 Despite progress, invasive species continue to pose a threat in protected areas globally

The first global-scale assessment of the phenomenon of invasive species was undertaken in the 1980s, as part of the international SCOPE programme on biological invasions. One of the many initiatives of the SCOPE programme assessed the threat of invasive species in protected areas. Invasions have increased greatly in extent worldwide since the 1980s, but how has the situation changed in protected areas?

A study led by Ross Shackleton (former C·I·B PhD student, Post-Doctoral Fellow and current C·I·B Associate, now based at the University of Lausanne in Switzerland) collated data for 21 of the protected areas around the world that were assessed in the SCOPE programme in the 1980s. The aim was to determine how the situation, in terms of numbers of invasive species, impacts, and management approaches, has changed over 30 years. The research also involved Louisa Wood (Centre for Environment, Fisheries and Aquaculture Science, UK), Llewellyn Foxcroft (SANParks and C·I·B Core Team Member), Peter Pyšek (Czech Academy of Sciences and C·I·B Associate), and Dave Richardson (C·I·B Director).

Of the taxonomic groups that were assessed, invasive plants showed the greatest increase in numbers of species present (an increase in 31% of protected areas) (Figure 9)(Shackleton *et al*. 2020; *Biol. Conserv*. **243**, 108424). As was the case in the 1980s, invasive plants are perceived to be the greatest threat to protected areas (60% of regional experts believe the threat level to be increasing form invasive plants in the respective protected areas). The number of invasive mammals has increased in 26% of protected areas. For all other taxa increases in number of invasive species are below 20%, and threat levels remains fairly stable, except for mammals which have shown a large decrease.

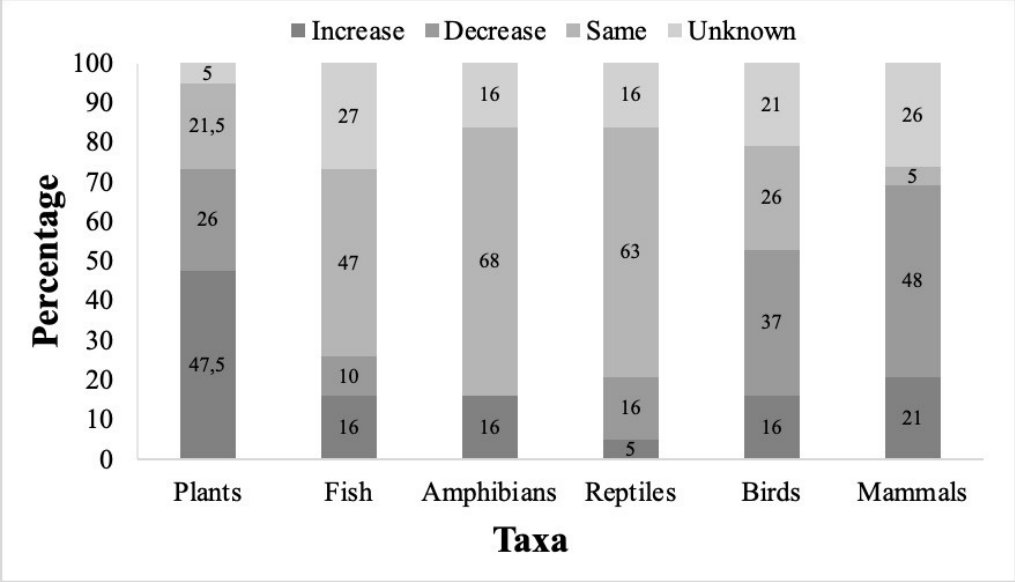


Figure 9. Changes in the number of different taxa listed as invasive between 1980s and 2018 in 21 protected areas across the globe. The proportion of change between different taxa were significantly different (LH-ratio = 46.078, p = 0.001) Shackleton *et al*. 2020; *Biol. Conserv*. 243, 108424).

Despite the increase in numbers and impacts caused by invasive species in protected areas, several management success stories were documented, and most protected areas are committed to invasive species management; 55% have long-term continuous control and 40% implement *ad hoc* management. The number of recorded invasive mammals has decreased in 43% of the protected areas in part due to good control, and there have been successful eradication initiatives of one or more species in more than half of the protected areas assessed.

There have also been successes in containing invasive species at the borders of protected areas over long periods, and there were examples of the control of widespread species though innovative adaptive management approaches and the introduction of biological control agents. It is imperative that these initiatives continue, otherwise the impacts of invasive species on biodiversity and ecosystems in protected areas could be much worse.

“This study offers a nice temporal comparison of how the situation with invasive species has changed in protected areas globally. Moving forward with analysis of larger sample sizes would yield clearer insights and could help us to better understand the drivers invasion dynamics in protected areas globally” said Ross Shackleton. “Co-ordination and centralisation of data would help to achieve this”.

A framework for reducing the impacts of invasive alien species in World Heritage Sites

World Heritage Sites contain cultural and natural heritage of outstanding value to humanity. The United Nations Educational, Scientific and Cultural Organization (UNESCO) has inscribed 1,121 sites worldwide, of which nine are in South Africa —including four natural sites: the Cape Floral Region Protected Areas; the Greater St. Lucia Wetland Park; Vredefort Dome; and Barberton Makhonjwa Mountain Land. South Africa has a responsibility to care for these sites, both as part of our own heritage and as custodians for the world. However, as with all such protected areas, they are threatened by global change and, in the case of South Africa, plant invasions in particular.

A team of international scientists, including four with C·I·B affiliations, devised a new monitoring and reporting framework to help managers track and respond to the threat of biological invasions (Figure 10). Lead author Ross Shackleton began the work while at the C·I·B as a Post-Doctoral Fellow, and completed it while employed at the University of Lausanne in Switzerland.

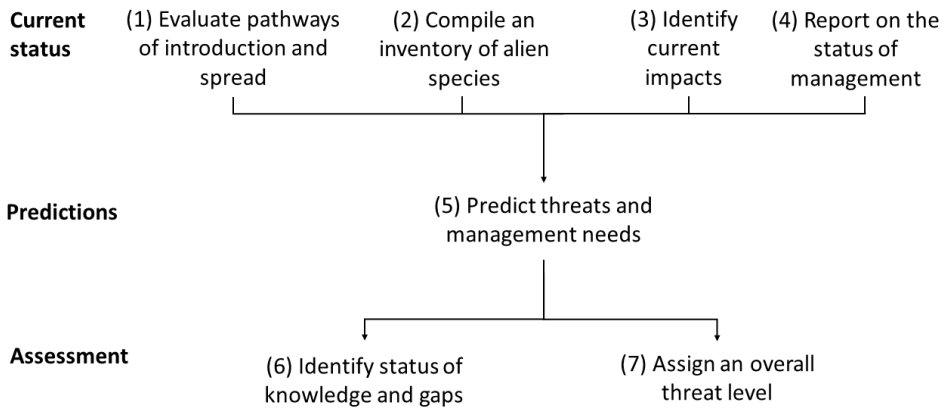


Figure 10. A proposed framework for monitoring and reporting on biological invasions and their management in natural and mixed World Heritage Sites globally. The result of the process (i.e. stage 7) is that each site is given an overall threat level ("very high", "high", "moderate", "low", or "data deficient"). (Shackleton *et al*. 2020; *Biodiv. Conserv*. 29, 3327-3347).

According to co-author and C·I·B Director, Dave Richardson "While it is clear to those working in these sites how much of a threat invasive plants pose to the biodiversity, demonstrating the costs and benefits of management is challenging". C·I·B Core Team Member John Wilson agrees: "If you can't measure it, you can't manage it".

The team assessed biological invasions and their management in 241 natural and mixed World Heritage Sites from documents collated by UNESCO and the International Union for Conservation of Nature (IUCN). They found that reports on the status of biological invasions were irregular or inconsistent. Information available for some sites was informative but it was very difficult to compare information between sites to produce summaries of the global status of invasions, and on trends, because no systematic method of reporting was followed. According to Ross Shackleton, “Detailed information on invasive alien species management undertaken in World Heritage Sites was available for fewer than half of the sites that listed invasive alien species as a threat”. He added: “There was clearly a need for an improved monitoring and reporting system for biological invasions in World Heritage Sites and other protected areas globally.”

The framework devised in this study grew from a monitoring system and set of indicators developed by the C·I·B and SANBI. It proposes protocols for collecting information and reporting on: pathways, the alien species that are present, impacts, management, predicting future threat and management needs, the status of knowledge and gaps, and, assigning an overall ‘threat score’ to the site. The study tested the proposed framework for seven World Heritage Sites.

Co-author Dr Arne Witt (C•I•B Fellow in 2016) says “We need urgent action right now to reduce the severity of threats from a wide range of invasive alien plant species, such *as Mimosa pigra* and *Prosopis juliflora*. We believe that the development of this monitoring and reporting framework is a step in the right direction to protecting areas”. The testing of the devised framework yielded new information. For example, the invasive alien species threat level indicated in the 2017 IUCN World Heritage Outlook for the Serengeti, Keoladeo, Doñana and South Africa’s Vredefort Dome was ‘data deficient’ or ‘low threat’ or ‘not listed’, whereas all of these sites can now be categorised as facing ‘moderate’ to ‘high’ threats from biological invasions. The Vredefort Dome, in the Northwest and Free State provinces is threatened by 45 invasive alien species, mostly plants but also some invasive fish species. However, the Working for Water (WfW) programme is actively managing many invasive species at the site to mitigate their impacts. Active management is also underway at the iSimangaliso Wetland Park World Heritage Site.

Dave Richardson says “World Heritage Sites face rapidly growing threats from a range of biological invasions which impact upon native biodiversity and the delivery of ecosystem services. Not only that, but invasive alien species are a financial burden as costs for management can be extremely high.”

The new framework involves the listing all alien invasive species present. This information will allow the tracking of changes in threats and of the implementation and level of success of management.

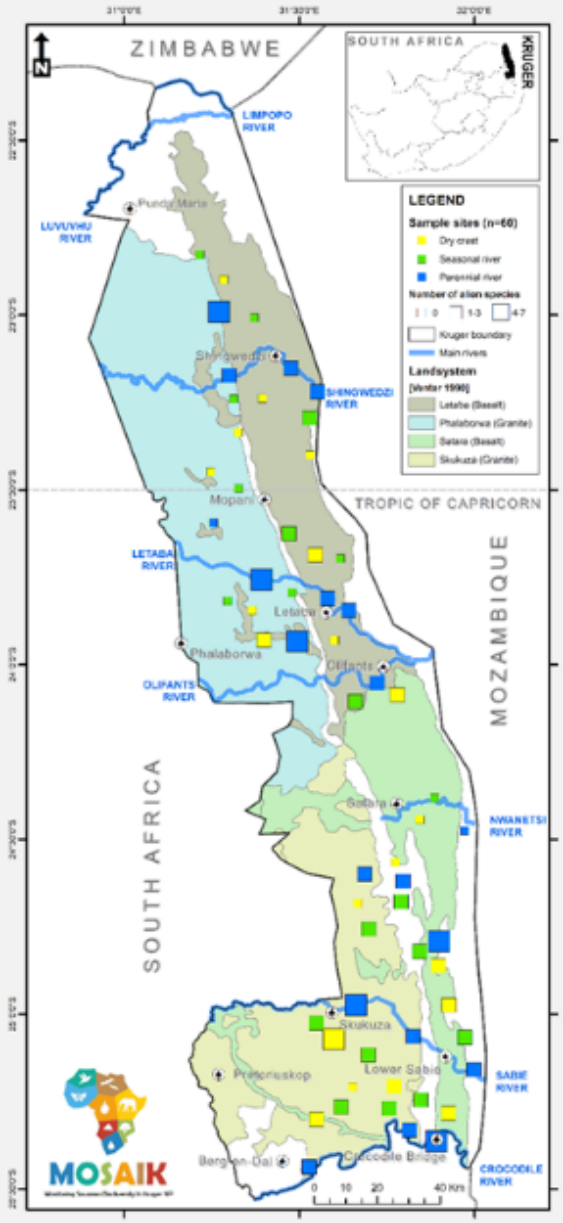
The study recommends that funding should be made available to conduct surveys at all under-resourced World Heritage Sites to inform the reactive ‘state of conservation’ assessments undertaken by UNESCO and IUCN, and that monitoring can be enhanced through ‘citizen science’ projects.

Naturalised alien plants in Kruger National Park

An intensive biodiversity assessment of the seasonal rivers and upland savanna in the Kruger National Park recorded 20 naturalised alien plant species; of these only four had previously been recognized as invasive, and one was a new record for the park (Figure 11; Pyšek *et al*. 2020; *NeoBiota* **60**, 61–77). This is the finding of a large collaborative programme of Czech and South African researchers, led by Petr Pyšek (Institute of Botany of the Czech Academy of Sciences and a C•I•B Associate), together with Llewellyn Foxcroft (SANParks and C•I•B Core Team Member).

As part of the Monitoring Savanna Biodiversity in the KNP programme, 60 sampling sites were established across the park in four different land systems and along primary or perennial rivers, major tributaries (seasonal rivers) and dry upland savanna areas. At each sampling site 50 × 50 m plots were surveyed for all plants, including naturalised and invasive alien species.

Figure 11. The Kruger National Park, showing the location of the 60 sampled sites, separated according to habitat and distributed across the four land systems. The size of the symbols indicates the number of alien plant species recorded in the plot (Pyšek *et al*. 2020; *NeoBiota* 60, 61–77).



Being the first survey of alien species at this scale allowed for assessing species that had not yet been reported from these habitats. It also aimed to shed light on species that may not be as well-known or easy to identify, and therefore overlooked by control teams or in rapid surveys. Most invasive alien plant control takes place along the major rivers that originate from outside the park. Little is known about the invasion of large tributaries, and the upland savanna areas have mainly only received attention in areas where specific species are known to occur.

The most widespread species was the tridax daisy (*Tridax procumbens*), and one species, Spanish needles (*Bidens bipinnata*) was a new record for KNP. The majority of aliens were concentrated along perennial rivers (60% of all occurrences), but some were repeatedly recorded at seasonal rivers as well and two of the most invasive species in KNP, sour prickly pear (*Opuntia stricta*) and famine weed (*Parthenium hysterophorus*), also occurred on dry crests away from water.

The results highlight the need for fine-scale, intensive surveys for alien plants in KNP, not only along the main rivers, but in other areas that have been considered less susceptible to invasion. As abundance data were also collected, follow-up surveys in the same plots after a few years will provide a good opportunity to determine whether these alien species that are considered now to be naturalised, are persisting.

"Although the magnitude of invasions in the habitats we surveyed is rather low and alien species rarely attained high cover, it is important to note that only a third of the plots were alien-species free, and that seasonal rivers harbour almost as many alien plants as perennial rivers, which indicates the potential of these

plants to spread," said Petr Pyšek. Llewellyn Foxcroft adds: "Recording new invasive species, as well as improving our information on alien species distribution and naturalised species, is an important step for developing management plans."

1.7 Restoration

1.7.1 When invasive alien plants fall, secondary invaders and/or weedy native species rise

Secondary invasion and/or dominance by weedy native species are often observed after clearing target invaders in South Africa (Figure 12) but these phenomena are seldom reported on and identified by name and/or correctly defined. This was the finding of a recent expert workshop and literature review conducted by a group of researchers led by C·I·B Associate Mlungele Nsikani.

"We often assume that native biodiversity recovery will follow the removal of invasive alien plants from ecosystems. However, invasive alien plant management is complex, and the removal of invaders may not always lead to full or even partial recovery of native biodiversity," explains Mlungele. "Clearing invasive plants often leads to secondary invasion and/or dominance by weedy native species instead of native biodiversity recovery."

Secondary invasion is the proliferation of non-target alien species following the removal of target invaders, while weedy native species dominance is the proliferation of native species that are not typically found and desired in the target area. Secondary invasion and/or weedy native species dominance can present significant barriers to restoration by taking up space and hindering seedlings of native plants to establish. The study evaluated the current knowledge on secondary invasion and/or weedy native species dominance in South Africa (Nsikani *et al*. 2020; *S. Afr. J. Bot*. **132**, 338-345); the authors found that the occurrence of secondary invasion and/or weedy native species dominance after clearing activities are not widely reported in the literature, and urged that more research is needed to inform a policy shift towards appropriate management of secondary invaders. Current policy on invasive plant management in South Africa focuses heavily on target alien invaders but lacks clear mechanisms and incentives to deal with secondary invaders and/or weedy native species, particularly those that are not already recognised as target invaders.

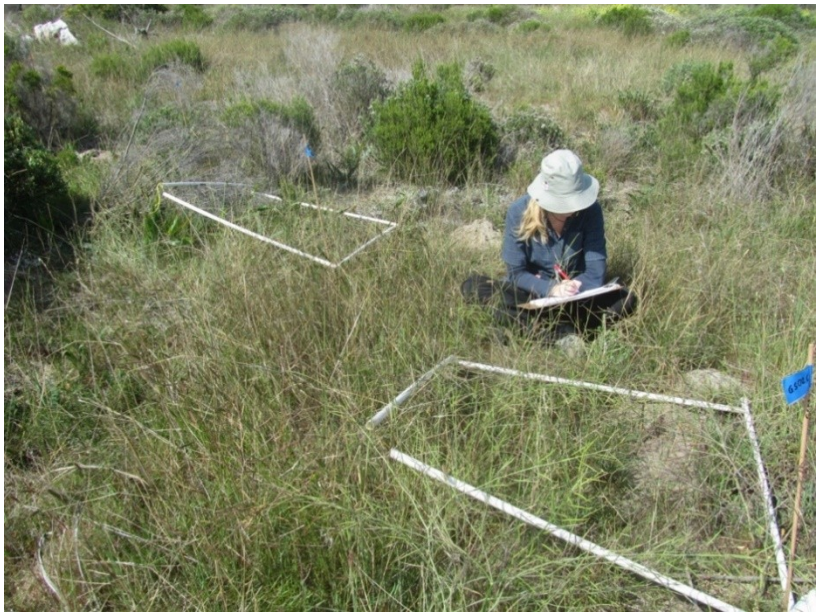


Figure 12. Site previously invaded by *Acacia saligna* (three years after clearing) at Glencairn on the Cape Peninsula, now dominated by secondary invaders and weedy native species. Photo: Mlungele Nsikani

"Secondary invasions are the new front line in the management of invasive alien plants," says Mlungele. "We need to start paying attention to this phenomenon and adapting our management techniques if we have any hopes of achieving our habitat restoration aims. Policy makers, researchers and practitioners need to recognise secondary invasion and/or weedy native species dominance as important barriers to native biodiversity recovery that require effective management."

1.8 Global environmental change and ecosystem services

1.8.1 The role of invertebrate conservation in safeguarding global biodiversity

Most of the world's ecosystems require diverse and abundant insect communities to function, yet conservation efforts typically overlook this widespread taxonomic group. For this reason, there is a clear need to identify threats and swiftly develop strategies to protect invertebrates.

A recent article put forward a call for the governments, researchers, and conservationists of the world to act now to address global insect declines. Led by Jeffrey A. Harvey from the Netherlands Institute for Ecology, the article was co-authored by 73 researchers, including C·I·B Post-Doctoral Fellow James Baxter-Gilbert (Harvey *et al*. 2020; *Nature Ecol*. *Evol*. **4**, 174-176). Insects are the most species diverse group of animals; they play crucial roles in ecosystem functioning as herbivores, detritivores, parasitoids, predators and pollinators.

They are vital to human food production, with many species pollinating crops and acting as biological pest control. Despite these roles, recent research has identified that up to 40% of all insects are threatened with extinction – which jeopardises both the natural world and human persistence.

The authors devised a roadmap for global insect conservation, including a list of immediate 'no regret' steps to be taken, as well as medium- and long-term actions. The no-regret actions address threats that we know impact insect communities, or are likely to, and will additionally have ecological benefits if properly addressed; these actions will either directly or indirectly benefit insects and ecosystems alike (Figure 13).

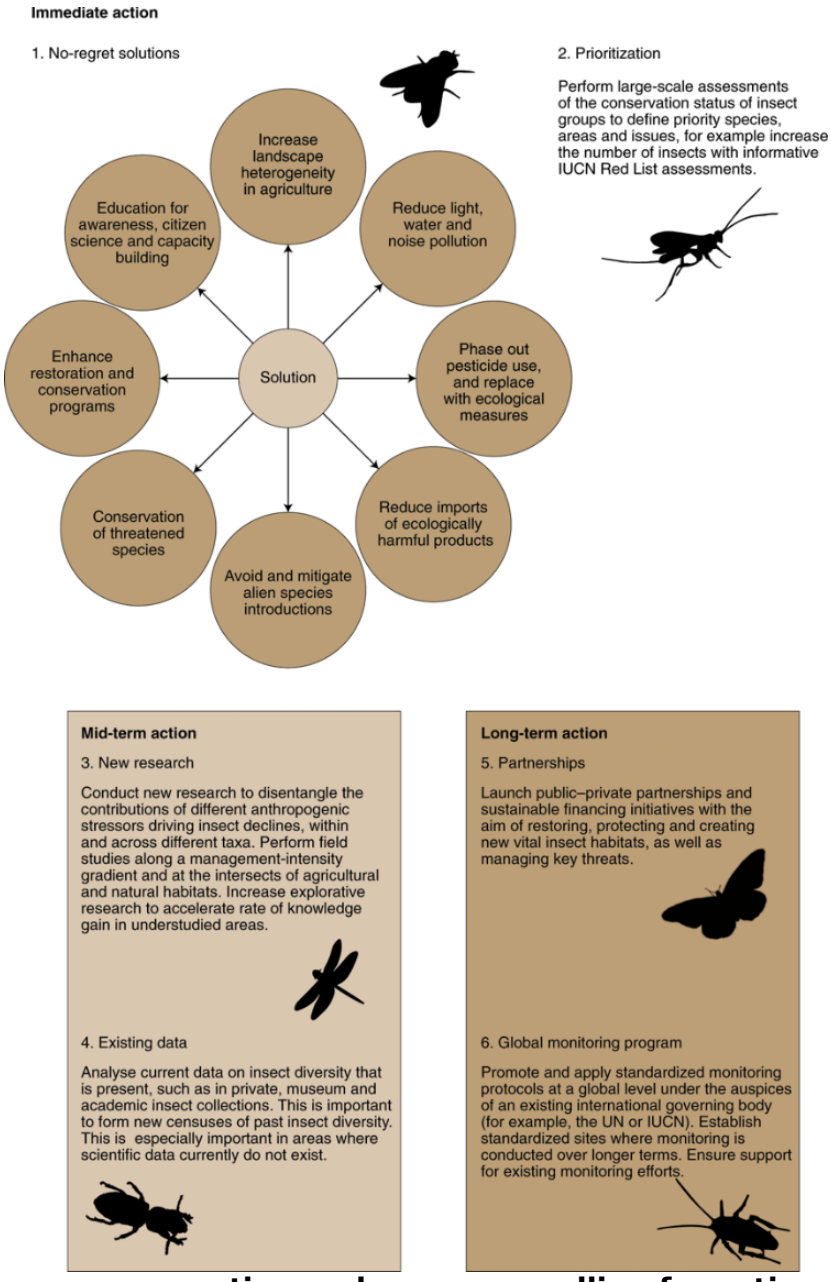


Figure 13. Roadmap to insect conservation and recovery, calling for action at short-,

intermediate- and long-term timescales (Harvey *et al*. 2020; *Nature Ecol*. *Evol*. 4, 174-176).

The threats facing insect populations are vast and diverse and the spread of invasive species has been associated with invertebrate declines. As such, understanding the role that invasive species play in insect declines, as well as the mechanisms that allow invasive species to spread and persist, are paramount if we are to prevent further insect diversity loss. As such, the work on invasive flora and fauna that the C·I·B undertakes will no doubt further our abilities to assist in insect conservation into the future.

“In the face of global biodiversity loss, conservation actions are needed more than ever. Yet, if we are to protect the typical conservation target species – the vertebrates, the fuzzy or feathery ones, all the individual favourite charismatic species each one of us has, then we must first protect the insects as they shoulder the burden of so much ecological function that allows the rest of life to persist” says James Baxter-Gilbert. This is not simply for those who are interested in entomology. The paper concluded that “there is now a strong scientific consensus that the decline of insects, other arthropods, and biodiversity as a whole, is a very real and serious threat that society must

urgently address" and that "we should not wait to act until we have addressed every key knowledge gap. We must act now."

1.8.2 How well do current methods of control for major invaders work under elevated CO_2?

Research conducted by C·I·B PhD student Blair Cowie and C·I·B Core Team member Marcus Byrne showed that herbicide is likely to become less effective in controlling the invasive famine weed (*Parthenium hysterophorus*) in the future as CO_2 levels rise. The study assessed the efficacy of glyphosate (herbicide) in controlling famine weed under the current atmospheric CO_2 level (400 ppm) as well as those anticipated in the near future (600 and 800 ppm)(Cowie *et al*. 2020; *Pest Manage. Sci*. **76**, 2324-2332).

Increases in atmospheric CO_2 have been shown to enhance the growth and reproduction of various weeds, helping to increase their invasiveness. However, the indirect effects of rising CO_2 levels may be just as concerning, particularly regarding chemical controls. Increases in plant growth, as a result of elevated CO_2, are suggested to dilute the effective dosage and limit the uptake and movement of glyphosate within the plant, making the herbicide less effective. Therefore, the use of glyphosate, which remains a common practice to manage famine weed in South Africa and globally, may be less successful in the future as CO_2 levels rise.

To assess this, famine weed plants were grown for five consecutive generations under three CO_2 levels of 400, 600 and 800 ppm. The results from this study showed that under our current CO_2 level (400 ppm), glyphosate remained effective, offering 100% mortality. However, the efficacy of glyphosate declined when applied to famine weed plants grown under elevated CO_2 levels (600 and 800 ppm). These plants suffered lower levels of damage from the herbicide, with some able to fully recover and produce viable seed, albeit at relatively low rates of 17 and 25%, respectively. The survival of plants, even at these low rates, is problematic as it is likely to lead to the development of less susceptible and potentially glyphosate resistant populations of famine weed in the field (Figure 14).

"Although this research highlights that glyphosate herbicides should remain a useful management tool, if applied correctly, under our current CO2 levels (~400 ppm), it also warns that South Africa should not become complacent with nor reliant upon these herbicides as long-term control for Parthenium" says Blair Cowie, lead author of the paper. He added that "ultimately, this promotes the need to better implement and enhance other, more promising controls, namely biological control and integrated management".

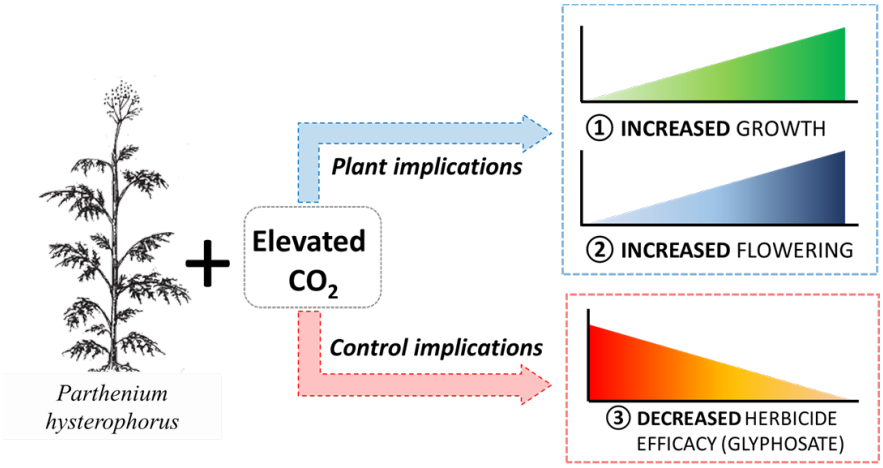


Figure 14. Famine weed (*Parthenium hysterophorus*) stands to benefit in terms of both growth and reproduction under elevated CO2 levels. These increases in growth are likely to make the weed less susceptible to herbicides, particularly glyphosate, in the future (Graphic: Blair Cowie).

1.9 The human dimensions of biological invasions

1.9.1 Invasive rodents and the pet trade in South Africa: Insights from Gauteng

The brown rat (*Rattus norvegicus*) and the house mouse (*Mus musculus*) are two of the world's worst invasive rodent species. They spread zoonotic diseases, damage crops and household items, outcompete native species for food, and prey on native bird species. These undomesticated species which live closely alongside and benefit from humans were accidentally introduced to South Africa largely through the shipping trade, and are currently widely sold as pets in the pet trade industry such as breeders, pet shops and online.

C•I•B PhD students Ndivhuwo Shivambu and Tinyiko Shivambu, former C•I•B student Rolanda Julius and C•I•B Core Team member Christian Chimimba surveyed pet shops across the Gauteng Province and collected rodent samples for genetic identification (Figure 15). Their results showed that some rodent individuals labelled as 'small rats' were in fact strains of *M. musculus* and other samples were identified as *R. norvegicus* strains (Maligana *et al*. 2020; *Afr. Zool*. **55**, 149–154). The work shows that pet shop owners lack the taxonomic expertise to identify the rodent species that they trade in. The rodents sampled were genetically affiliated to both wild and laboratory strains of *M. musculus* and *R. norvegicus*. This suggests that pet rodents are sourced from both the wild and laboratories, with those from the latter possibly being released into the wild.

The researchers recommend continued monitoring of the sale of these invasive rodents to prevent further introduction and spread. The findings of this

study will be useful inputs to the development of national policies and regulations for invasive rodents in the pet trade industry in South Africa.

"Given the lack of taxonomic expertise in the pet trade industry, we believe that the pet trade industry will contribute to the future invasion of these and other species. It is therefore important to develop an accurate inventory of non-native pets as this can be used for educational purposes, the development of policies and regulations, appropriate decision-making and management strategies," explains Ndivhuwo Shivambu.

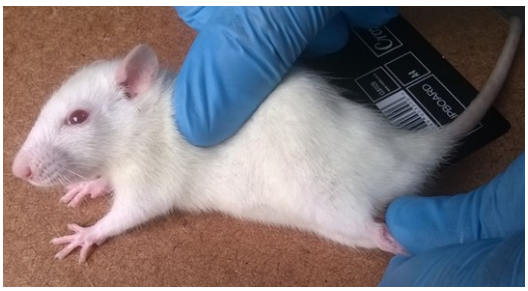


Figure 15. Ndivhuwo Shivambu collecting tissue samples from a pet rat in a pet shop in Gauteng. (Photograph: Ndivhuwo Shivambu).

1.10 Integrative work in the field of invasion science

1.10.1 Sharing knowledge to improve management outcomes

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

Many organisations in South Africa have invasive alien species management as one of their responsibilities (or 'mandates'); these include

provincial nature conservation authorities (CapeNature), protected area managers (SANParks), biosecurity authorities (DEFF) and NGOs such as the National Society of the Prevention of Cruelty to Animals (SPCA), which is charged with ensuring that animals are not mistreated. In addition, many universities and research organisations conduct research on invasive alien animals.

The working group brings these role-players together two to three times a year to discuss ongoing projects and emerging issues. The geographical scope of the group is largely defined by the Cape Floral Region, which includes most of the Western Cape and the western part of the Eastern Cape. In addition to being a forum for learning and discussion, the group aims to enhance cooperation among stakeholders such as implementing agencies and researchers, and thereby improve the management of invasive animals in the Greater Cape Floristic Region.

The working group was regularly attended by 19 organisations at national, provincial and local municipality level. The group discussed and advised on 35 animal groups or species from earthworms to mallards to feral pigs (Figure 16). Discussions led to the establishment or supported eight fully-fledged projects that address research on management and control methods in House Crows, Guttural Toads, Mallard Ducks, Feral Pigs, invasive freshwater fishes, marine invasions, including European Shore Crabs, Wasps and Earthworms. In addition to assisting decision makers, the forum also supports the work of many C·I·B post-graduate students, for example the PhD project of Giovanni Vimercati on the invasion of Guttural Toads in the Western Cape (this species is native to the summer rainfall parts of SA), Kirstin Stephens' MSc project on the effects of the Mallard Duck (native to north America and Eurasia) on our native ducks (through hybridisation with native yellow-billed ducks) and Clova Mabin's PhD study on feasibility of marine eradications using European Shore Crabs as a case study.

For researchers in the working group, the discussions provide valuable material for identifying research projects and anchoring them in real-world needs and priorities. When students working on invasive alien animal projects attend CAPE IAAWG meetings, they receive input, feedback and suggestions on the applied aspects of their work, as well as exposure to real world issues and insight into policy and management. Students also realise the importance of practical issues that need to be considered when research results are implemented. Their perspective on their work is broadened to include issues that many researchers do not become aware of until much later in their careers.

The group has played a vital role in linking researchers, managers, and policy-makers and contributed to better communication with the public, smoother contract efficiency and logistics, and helped to address conflicts between role players. Group members have collectively learnt about the

importance of including ethical and rights considerations in the decision-making processes for invasive alien animal management.

The CAPE IAAWG requires little funding and relatively few hours are spent in meetings, making it an efficient tool for improving invasive alien species management in South Africa provinces and cities. The group has been highly productive, thanks to the participating organisations for providing the time (and the joint secretariat of Cape Nature and City of Cape Town).

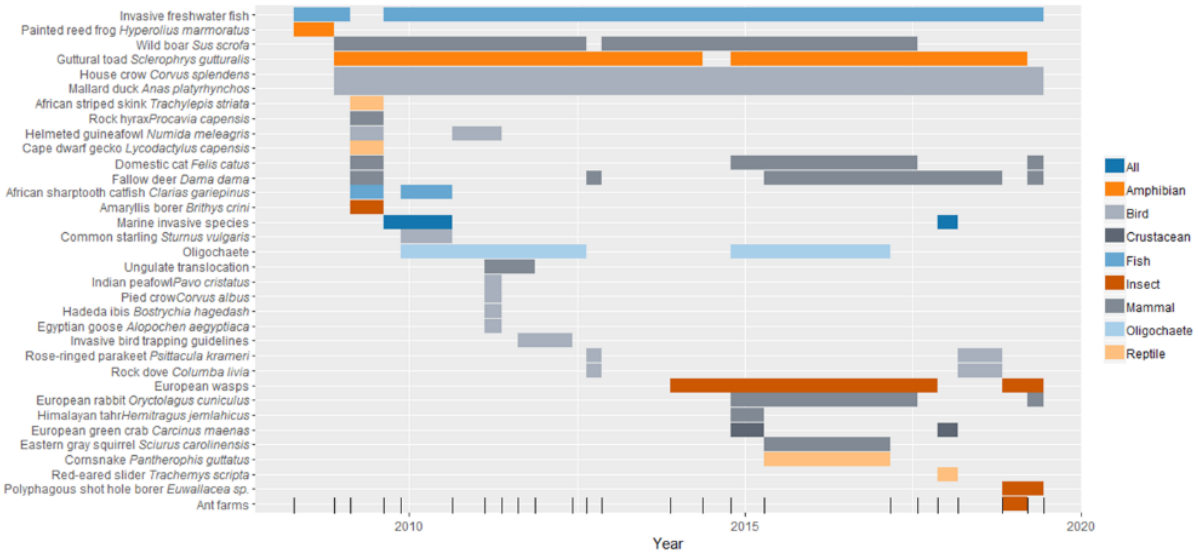


Figure 16. Species and topics discussed over time at the CAPE Invasive Alien Animals Working Group meetings. The bars span the period over which a species appeared on the agenda for discussion. Ticks on the x-axis represent the dates that meetings took place.

1.10.2 "Frameworks used in Invasion Science" – outcomes of a C·I·B workshop

As is the case in most fields of science, the study of biological invasions has advanced in a non-linear way. Progress in invasion science has been punctuated by the development of numerous schemes or constructs that have proposed bold explanations, syntheses, hypotheses, and theories. Some of these have served as important roadmaps or signposts that have directed research attention. Scientists working on questions related to developing or implementing frameworks for invasion science were invited to develop draft manuscripts on particular topics in advance of the workshop, share these with other attendees before the workshop, and present them at the workshop.

In November 2019 C·I·B hosted an international workshop on "Frameworks used in Invasion Science". Many C·I·B-affiliated researchers and students spent a large part of 2020 working on papers from this workshop. The aim of the

workshop was to explore frameworks in invasion science from multiple perspectives, to come up with a range of different types of papers (ideas, perspectives, reviews, guidelines, and practical case-studies) (Figure 17). The scope of these contributions was unified by the workshop aim, which was developed into the “Stellenbosch Challenge for Invasion Science”: Can invasion science develop and improve frameworks that are useful for research, policy or management, and that are clear as to the contexts in which the frameworks do and do not apply?

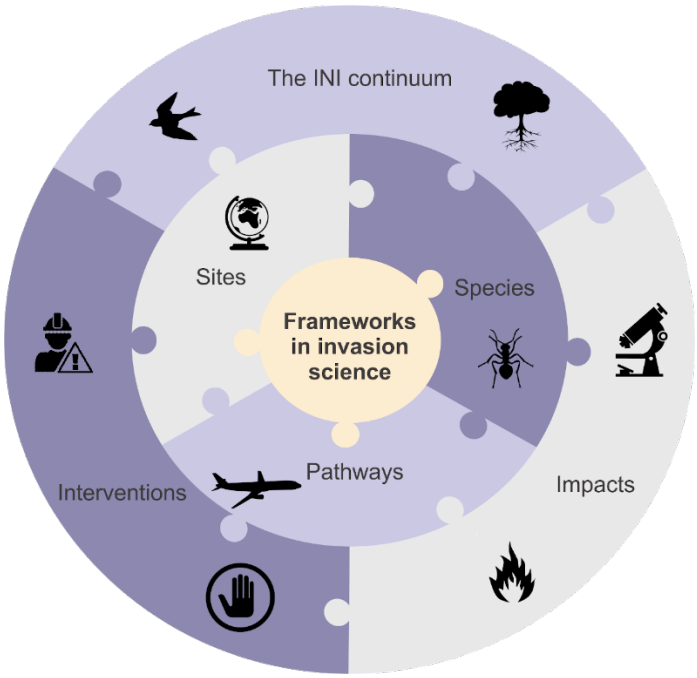


Figure 17. A schematic showing the range of issue and themes addressed by frameworks in invasion science (Wilson *et al.* 2020; *NeoBiota* 62, 1–30)

Interactions at the workshop and collaborations over much of 2020 led to a bumper special issue of the journal *NeoBiota* comprising 24 papers (20 of them with C·I·B-affiliated authors) that addressed the Stellenbosch Challenge by:

- applying existing frameworks to new data and contexts;
- reviewing how the frameworks have been adopted and used;
- developing useable protocols and guidelines for applying frameworks to different contexts;
- refining the frameworks in light of experience;
- integrating frameworks for new purposes;
- identifying gaps; and
- developing new frameworks to address issues that are currently not adequately dealt with.

The editorial team consisted of five C·I·B Core Team Members, two former C·I·B Fellows, and two leading international invasion science experts. Lead editor, C·I·B Core Team Member John Wilson, says: “The development of frameworks and their codification as standards demonstrates that invasion science is maturing as a discipline. However, this special issue has done much to demonstrate the importance of testing the frameworks in the light of real-world experience. Frameworks and standards are vital for policy makers, managers, and scientists but only if they are useful”. C·I·B Director Dave Richardson added: “I believe that this special issue, and the Stellenbosch Challenge more generally, has provided a much needed critical examination of frameworks in invasion science. It has generated exciting insights for how the field should progress.”

2 EDUCATION AND TRAINING

2.1 Under-graduate teaching

The C•I•B run course, *BDE 345 Invasion Biology* (Stellenbosch University, 3rd year, 16 credits), was conducted online led by three C•I•B core-team members, Professors Robinson, Measey and Richardson. The course deals with the core aspects of invasion biology, and uses African based context and examples to describe both problems and solutions posed by biological invasions. The course was attended by 53 students who achieved a high pass rate, despite the constraints of the online only course content.

2.2 Post-graduate training and early career researchers

Table 1. Post-graduate students funded by the COE grant

Category	No.	%
All students	25	100
Academic level		
Hons./4th year	6	24
Masters	11	44
PhD	8	32
Gender		
Male	7	28
Female	18	72
Student demographics		
Black	14	56
White	6	24
Coloured	5	20
Asian	0	0
Disability		
Disabled	0	0
Not disabled	25	100

2.3 Career development/alumni

Our graduates are present in many key organisations globally; several alumni working in Africa participated in the African Networks and IPBES panel discussions at the first online Annual Research Meeting in November 2020. Another examples is that in 2020, Cape Peninsula University of Technology included invasion biology in their advanced diploma in Marine Science because the course is being co-ordinated by C·I·B alumnus, Dr Koebraa Pieters. The table below provides a sample of C·I·B alumni and their current positions in 2020.

Table 2. Current whereabouts of a selection of C·I·B alumni

Dr María Loreto Castillo, Researcher & IPBES Fellow

Dr Ryan Blanchard, Council for Scientific & Industrial Research

Dr Solomon Newete, Institute for Soil, Climate and Water, ARC

Dr Sebataolo Rahlao, South African National Biodiversity Institute

Dr Joice Ndlovu, Senior Lecturer, Chinhoyi University of Technology, Zimbabwe

Ms Dianah Kutama, Real Time Analyst, Luno

Dr Lubabalo Mofu, Post-Doctoral Fellow, SAIAB

Mr Phil McLean, Bioremediation Manager, DEA&DP

Dr Ross Shackleton, Lecturer, University of Lausanne, Switzerland

Ms Joy Mangachena, PhD candidate, Griffith University, Australia

Dr Charlene Janion-Scheepers, Lecturer, University of Cape Town

Dr Mlungele Nsikani, Senior Scientist, South African National Biodiversity Institute

2.4 Student support programme

The student support programme usually includes a two-day On Boarding workshop in the first semester and then a topic-specific workshop in the second semester. Due to the COVID-19 pandemic the On Boarding workshop was converted into a one-day online webinar. The morning session gave students the opportunity to introduce themselves and to meet key C·I·B staff members. The afternoon session was an interactive discussion of the key elements that enable student success at post-graduate level. The online event was attended by ten new C·I·B students; C·I·B staff members Dave Richardson, Suzaan Kritzinger-Klopper, Erika Nortje and Sarah Davies participated in the morning session.

An informal survey of student wellbeing within the C·I·B context, during the peak of the COVID pandemic, suggested the need for a focus on emotional and physical wellbeing. Thus, two follow-up “coffee bar chats” were introduced. The first took place online on 31 July 2020 and was attended by seven post-graduates and the second took place online on 3 September 2020 and was attended by six post-graduate students. The “coffee bar chats” replaced the topic specific workshop as there was a greater need for more ongoing support for challenges that arose during the year. This support programme came to an end at the end of 2020 due to the financial cutbacks and staff retrenchment.

3 NETWORKING

3.1 Annual Research Meeting

The C·I·B held a vibrant and interesting online ARM on 12 and 13 November. The meeting included two keynote speakers, two panel discussions and 34 student speed presentations. Prof. Dave Richardson opened the meeting by presenting the C·I·B’s achievements and challenges in 2020 to the assembled team and partners. Dr Urs Schaffner of CABI, Switzerland, spoke about the East African Woody Weeds project in which the C·I·B has participated since 2011. His talk was titled “Integrating ecological and socio-economic impacts of *Prosopis juliflora* (mesquite) in Eastern Africa to inform management”. It addressed how mesquite has become dominant (and yet is still promoted by governments and NGOs). The collaborative project is testing and promoting sustainable land use practices in mesquite-invaded areas of Ethiopia, Kenya and Tanzania to mitigate the negative impacts of this highly invasive tree.

Two panel discussions were held on “African invasion biology networks” and “The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)”.

3.1.1 Discussion on African invasion biology networks

The aim of the African networks panel was to enhance the C·I·B's interactions with associates and alumni in other African countries in keeping with its new focus on developing an African funding network for invasion science, as outlined in the 2020-2022 Business Plan. To this end we involved three alumni, one associate and one new potential partner in the discussion.

Panel members

Dr Solomon Newete from the Agricultural Research Council's Institute for Soil, Climate and Water is a former Post-Doctoral Fellow of C·I·B (University of the Witwatersrand) with research interests in invasive alien plant, biological control, environmental restoration and Remote Sensing.

Dr María Loreto Castillo, is an independent researcher and IPBES Fellow working in Cape Town, South Africa. Dr Castillo has a PhD in Botany (Stellenbosch University), having worked on the Eastern Africa Woody Weeds project. She is interested in the eco-evolutionary aspects of biological invasions as their management.

Dr Joice Ndlovu is an alumnus of the Centre for Invasion Biology at Stellenbosch University, and is currently a Senior Lecturer at Chinhoyi University of Technology in Zimbabwe. Dr Ndlovu has worked on cactus invasions in Zimbabwe, and is generally interested in the phylogenetics and phylogeography of invasive plants and using molecular genetics data to trace the origins of invasions.

Mr Griffin Shanungu, Zambia Cranes and Wetlands Conservation Programme, International Crane Foundation/Endangered Wildlife Trust partnership joined the panel to discuss his work addressing the interactions between wetland vegetation, threatened wetland birds and large mammalian herbivores in freshwater wetlands. Alien plant invasions such as the spread of *Mimosa pigra* are particularly important.

Dr Arne Witt is a former C·I·B visiting fellow and Regional IAS Coordinator (Africa, Asia, Caribbean) at CABI. The main focus of Dr Witt's work has been on policy development, awareness creation, capacity building, and development and implementation of best management practices, particularly biological control of invasive plants.

3.1.2 Discussion on IPBES

This high-level panel discussion addressed reviewed the background of IPBES and the invasions assessments, progress to date, and how the assessment could

potential affect the way that invasions are managed in the future. We were fortunate to both two of the co-chairs of the IPBES invasive alien species assessment, as well as various C•I•B-affiliated members of IPBES on the panel. Discussion focussed on key challenges facing the assessment, implications for invasions and their management in Africa, and on the global landscape of invasion science research and the implications of this for challenges facing the C•I•B.

Panel members

Prof. Anibal Pauchard is Co-Chair of IPBES. He is Professor at the Faculty of Forestry Sciences in the University of Concepción in Chile and the founder and director of the Laboratory of Biological Invasions (LIB). His research is focused on biological invasions ecology and the impacts they cause on biodiversity and ecosystems functions. Through the use of multi-scale approaches, based on field observations and experiments, he has studied the synergies that exist between global change agents and plant invasions in mountain ecosystems. Anibal is co-chair of the IPBES assessment on invasive alien species and their control.

Dr Ryan Blanchard is a Senior Researcher in the division of Biodiversity and Ecosystem Services, Council for Scientific and Industrial Research. He is a research associate at the Centre for Invasion Biology. His research focuses on various drivers of change such as biofuels, invasive alien species and climate change and their impacts on biodiversity and ecosystem services. Ryan is currently a lead author on the chapter addressing direct and indirect drivers of biological invasions in the IPBES assessment on invasive species and their control. Dr Blanchard is an alumnus of the C•I•B at Stellenbosch University.

Prof. Helen Roy, UK Centre for Ecology & Hydrology, Oxfordshire, UK is Co-Chair of IPBES**.** Her research focuses on the effects of environmental change on insect populations and communities. She is particularly interested in the dynamics of invasive alien species and their effects on biodiversity and ecosystems. She is one of the co-chairs for the IPBES global thematic assessment on invasive species and their control. Helen also enjoys science communication and public engagement with research which led to her interest in citizen science.

Prof. Laura Meyerson, University of Rhode Island serves on the faculty senate, directs both the Restoration Ecology and Environmental Science minors and conducts research on biological invasions. She is the Associate Editor-in-Chief for the journal Biological Invasions and an Associate Editor for NeoBiota. She is an International Science Advisor for the C•I•B and is currently co-leading a chapter on trends in biological invasions for the forthcoming IPBES report on invasive species.

Dr Sebataolo Rahlao, South African National Biodiversity Institute leads a programme of work that generates knowledge and evidence for policy and legislative decision-making on invasive alien species in South Africa. This includes detection, eradication planning and coordination of emerging invasive alien species, research relating to invasives taxonomy and risk analyses. He is also co-leading the chapter on trends and status of biological invasions for the IPBES assessment. Dr Rahlao is an alumnus of the C•I•B at Stellenbosch University.

3.1.3 Presentations of student work

Post-graduate students supported by the COE grant and all other grants and partners presented their work at the meeting in six sessions of speed presentations (5 minutes per student) as follows:

- “Getting inside invaders” Chair: Josie South
- “Impacts of invasive species” Chair: Heidi Hirsch
- “Ecological Interactions” Chair: James Baxter-Gilbert
- “Restoration: Problems and Perspectives” Chair: Jan-Hendrik Keet
- “Regulating and Controlling Invasions” Chair: Tainã Loureiro
- “South Africa and its invasive species - a multi-faceted dance.” Chair: Anandi Bierman.

The presentations were evaluated by a voluntary panel of 12 Core Team Members based on their scoring of Scientific quality, Innovation, Communication, Impact potential and Response to questions. The best presentations were selected for each post-graduate level presenting (masters and doctoral), and a list of special commendations was made, due to the high quality of the presentations (Table 3).

Student Travel Award

The Masters Travel Award was awarded to **Amy Collop** (Stellenbosch University) for her presentation of her thesis work titled “A global assessment of the population structure of *Harmonia axyridis* - How did South Africa become invaded?”. The Doctoral Travel Award table was swept by **Phikolomzi Matikinca** (Stellenbosch University) for his work on “Ocean warming and acidification: potential implications of changes in the marine environment for alien fouling biota”

Table 3. Special commendation for the ARM student presentations

Special commendations for PhD presentations	
Henrika Bosua	Stellenbosch University

Emily Jones	Nelson Mandela University
Duduzile Ngwenya	Stellenbosch University
Anneke Schoeman	University of the Free State
Alekzandra Szewczuk	Wits University
Dewidine van der Colff	Stellenbosch University

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. MOUs with partner organisations

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

4 INFORMATION BROKERAGE

4.1 Iimbovane Outreach Project

In 2020, the Iimbovane team has interacted with 293 learners (from Luhlaza Secondary School, Riversonderend High School, Swartberg Secondary School, Emil Weder Secondary School, Gerrit du Plessis Secondary School, Augsburg Gymnasium) between January and March 2020 through school-based activities. These school-based activities included a theoretical lesson on biodiversity and

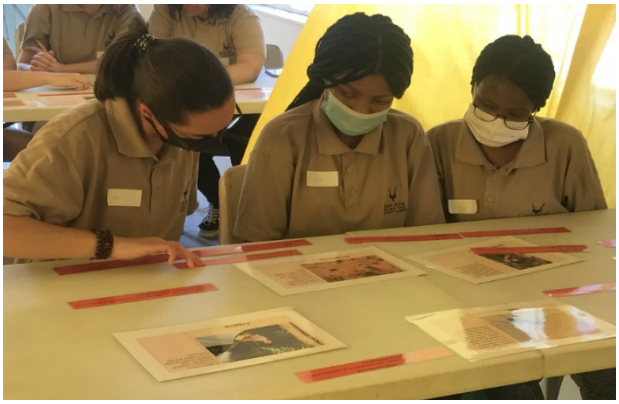
invasive species as well as the practical task of collecting invertebrates in a scientific manner. In addition to the project's school-based activities, Iimbovane also hosted an information session and exhibit at the annual Western Cape Education Department (WCED) Biodiversity Careers Expo in the Karoo Desert National Botanical Garden in Worcester on 5 March 2020. Approximately 70 learners from schools in the area attended the event. Learners visiting the Iimbovane exhibit were introduced to a variety of careers that are offered in biological sciences, the subjects needed and the entry requirements.

Prior to the COVID-19 lockdown, Iimbovane trained learners on the value of biodiversity. Here learners from Gerrit du Plessis Secondary School (Riversdal) and Swartberg Secondary School (Caledon) are collecting ants in their schoolyards. (Photo: Dorette du Plessis)

At the end of March 2020, the national lockdown was declared in response to COVID-19 and project activities had to be suspended. Efforts to manage the spread of COVID-19 have had severe impacts on the schooling system and after consulting with the Western Cape Education Department (WCED) and educators from Iimbovane partnership schools, it became clear that the project team would not have access to learners for most of the 2020 school year. Lockdown restrictions and changes in the annual school calendar forced us to cancel our holiday programmes and workshops that were planned for 2020. In response to these challenges, the Iimbovane team set up alternative ways of supporting educators and learners in participating schools. We developed a series of series of tools and activities that can be used remotely by educators within their classroom time, (1) online lessons based on our annual school-based activities for our educators; (2) a virtual laboratory tour of our Iimbovane research laboratory; (3) classroom lessons to selected schools through the Microsoft Teams online platform.

In October 2020, the Iimbovane project team set off to the Karoo National Park in Beaufort West, to train the park's Junior Rangers on ant diversity. The South

African National Park Junior Rangers is a one-year programme for young volunteers aged between 12 and 18 that have a passion for conservation in which they are exposed to the park's conservation functions. The Iimbovane workshop began at the community hall where the enthusiastic group of 12 learners explored the methods which scientists use to collect ants as well as their advantages and disadvantages. It was then time to go outside and geared with their 'pooters', and other sampling equipment, the group scrambled through succulents in search of different species of ants. The day ended with close observations of ants under the microscope during which the group were exposed to ant morphology and the scientific naming of ants.



Ant identification training workshop for SANPARKS Junior Rangers in the Karoo National Park, Beaufort West. (Photo: Dorette du Plessis)

In 2020, Iimbovane's efforts to deliver hands-on biodiversity education to the youth received a welcome boost, thanks to a generous donation from the Mapula Trust. The Mapula Trust contribution will be used to support classroom lessons and hands-on sampling in schoolyards. Life Science educators can also look forward to training opportunities to clarify the concept of biodiversity, its significance and more generally to improve the quality of biodiversity science teaching in classrooms.

Ant data that was collected by learners and educators from Iimbovane partnership schools between 2006 and 2014 contributed to yet another scientific paper. The paper uncovered that behavioural traits (when each ant species 'chooses' to stop searching for food) were able to predict the occurrence and abundance of each species much better than physiological traits (when each ant is too warm or too cold to perform any function). This indicates that some species will benefit from warming temperatures as their window of opportunity for seeking out food will increase, while other species will have a narrower window for searching for food. By identifying which ant species will be affected, and how, the researchers will better identify the winners and losers of climate

change, predict non-native species invasions and impacts, and improve management outcomes of South Africa's unique ecosystems. The paper was published in the *Journal of Animal Ecology* and can be viewed here: http://dx.doi.org/10.1111/1365-2656.13358

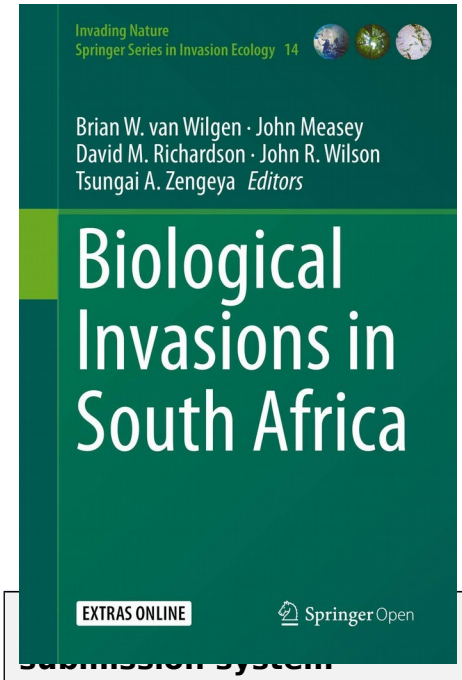
4.2 Media highlights

The complete list of media mentions can be viewed in the media interactions section of the report; however, there are a few highlights that stood out.

The contribution of C•I•B Associate, Ross Shackleton, C•I•B Core Team Member, John Wilson, and C•I•B Director Dave Richardson to a paper, published in the scientific journal, *Biodiversity and Conservation,* drew attention from both local and international media platforms. The paper, which described a new monitoring and reporting framework to help protect World Heritage Sites from invasive alien species, led to articles in newspapers such as *Cape Argus*, *Cape Times* and *Die Burger*. The research was further mentioned in articles on online platforms such as *Science Daily*, *Phys.org*, *Netwerk24, Stellenbosch News, The Conversation* and *Maroela Media*. The paper was further publicised a radio interview with Dave Richardson on *Cape Talk.*

In November 2020, a paper by C·I·B Post-Doctoral Fellow, James Baxter-Gilbert and C·I·B Core Team Member, John Measey, in the journal *Biology Letters*, received wide attention in the media. The paper, which found that, the overall body size of invasive Guttural Toads on the islands of Mauritius and Réunion has been reduced by up to a third compared to their counterparts in South Africa scarcely a hundred years after their introduction. These findings are an important step in understanding how quickly species change their morphology on islands, and led to articles in newspapers such as *The Star* and *Cape Times*. Online articles about the paper appeared on sites including *Science news*, *The Hindu*, *Seychelles Nation*, *New Scientist*, *All Africa*, *Phys.org*, *Cape Times*, *Reptiles Magazine*, *The Conversation* and *Times Live*. The paper received further exposure through a radio interview with James Baxter-Gilbert on SAfm. The paper was also picked up by Today's Science - America's leading publishers of print and online reference materials for the school and library market.

The contribution of several C·I·B members and partners to the first open access encyclopaedic book on all aspects of biological invasions in South Africa resulted in articles in the media. The book entitled, *Biological Invasions in South Africa*, was compiled by 104 authors and comprise of 31 chapters covering all aspects of biological invasions in South Africa. The launch of the book has led to articles in Landbouweekblad, *The Witness* and on online platforms *EurekAlert! Science News* and *Netwerk24*. Editor of the book, Brian van Wilgen, was also interviewed on *Channel Africa* and *Cape Talk*.



The invasive harlequin ladybird may ultimately not be able to adapt to climate change, despite the fact that it has successfully invaded four continents over the last two decades. This finding, published by C•I•B Core Team member, Susana Clusella-Trullas and colleagues, in the journal *Evolution,* received various mentions in the print media and has led to newspaper articles in the *Cape Argus*, *Beeld*, *Cape Times* and *Die Burger*.

4.3 Web-based services and social media

Submission system	https://ir.sun.ac.za/cib
231 items were submitted to the IRSS during the reporting year **74** items requested via IRSS document request feature	
Web page	https://blogs.sun.ac.za/cib
New site released beginning of June 2020. Old site remained operational as content was transferred throughout the year. **14 865 | 7159** unique visitors (old and new respectively) **24 171 | 17 518** unique page views Most visitors are from North America, Africa, and Europe. The new site, during the period June-Dec 2020, engaged 4928 new visitors and 1943 returning visitors.	
Facebook	https://www.facebook.com/centreforinvasionbiology
1579 followers | **1487** like this page **39** posts | **353** viewers per post (average) Top 5 posts:	

Date	C•I•B nugget	People reached
26 Jun	*Scientists warn of increasing threats posed by invasive alien species*	1900
15 May	*Acacia-released phytochemicals help invasive and native species establishment*	616
12 Jun	*Controlling famine weed under elevated CO2: a troubling future ahead?*	583
24 Feb	*Review confirms the value of biological control*	533
1 Jul	*Invasive plants are more phytochemically diverse than native counterparts*	511

Twitter	@invasionscience
4158 total Tweets | **1436** followers Per day average: **417** impressions | **64** link clicks | **28** retweets | **75** likes | **8**	

replies
Top Tweet: 1 June *Bursaries to study with CIB are open...* [**14250** impressions]

5 SERVICE PROVISION

5.1 IPBES

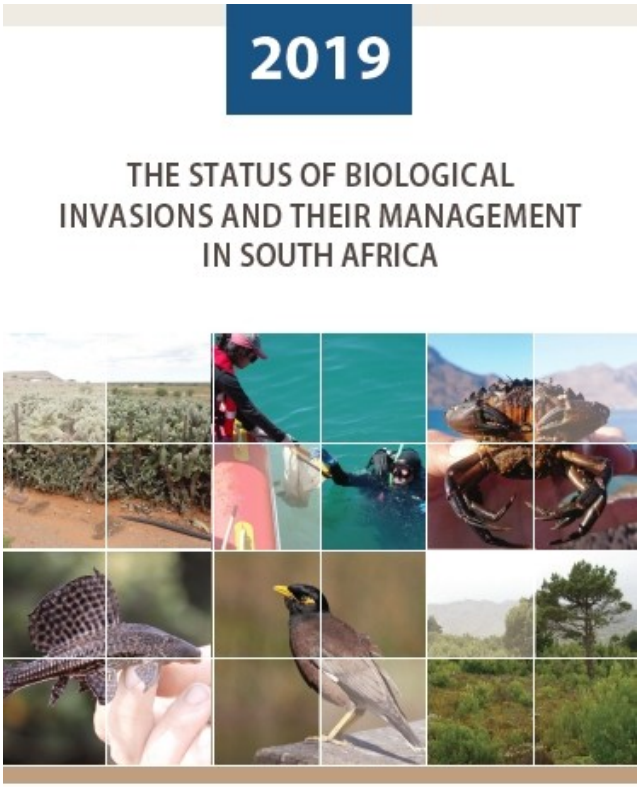
The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) is an independent intergovernmental body, established in 2012 by Governments, and currently has 137 members. Often described as the 'IPCC for biodiversity', the aim of IPBES is to strengthen knowledge foundations for better policy through science, for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development.

IPBES has undertaken assessment a wide range of specific themes of global importance relating to biodiversity and ecosystem Services. Completed assessments have included "Pollinators, pollination and food Production" (2016); "Land degradation and restoration" (2018); "Sustainable use of wild species" (2021). There have also been assessments on methodological issues ["Scenarios and models" (2016); "Values" (2021)] and regional and global-level overviews [Regional assessments of Biodiversity and Ecosystem Services (2018). The "Global assessment of biodiversity and ecosystem services (2019)] has been instrumental highlighting the dire status of biodiversity and global declines.

Due to the rapidly increasing threat by invasive alien species and the urgent need for international cooperation, IPBES began a thematic assessment on thematic assessment of invasive alien species and their control in 2019,. This assessment, scheduled for completion in 2022 aims to assess the threat that invasive alien species pose to biodiversity, ecosystem services and livelihoods and the global status of and trends in impacts of invasive alien species by region and sub-region, taking into account various knowledge and value systems.

The C·I·B is involved in the IPBES assessment in several ways. Several C·I·B core team members are (or were) involved as Lead Authors of chapters: Llewellyn Foxcroft, Sebataolo Rahlao (Coordinating Lead Author) and Olaf Weyl (until his death in November 2011). C·I·B core team members Dave Richardson and John Wilson are Review Editors. C·I·B associates Ryan Blanchard and Petr Pyšek are Lead Authors, C·I·B international scientific advisor Laura Meyerson is a Coordinating Lead Author, and a former PhD student Maria Loreto Castillo was selected as one of 12 IPBES fellows. C·I·B team members have also been consulted in various other ways.

5.2 National Status Report on Biological Invasions



Biological invasions are a major threat to South Africa's biodiversity, economy, and sustainable development. The National Status Report on Biological Invasions is part of South Africa's commitment to alleviating these impacts, and the C·I·B participated in producing the second edition of the report in 2020. The report provides a comprehensive national-scale assessment with contributions from 36 experts from 16 institutions. The second edition of the National Status Report was published in 2020 and will be launched early in 2021. [1]

The South African National Biodiversity Institute (SANBI) has entered into a collaboration agreement with the Centre for Invasion Biology to provide support to SANBI with the production of the second National Status Report for South Africa. Under this agreement Prof. Brian van Wilgen (Emeritus Core Team Member) provides mentorship and assistance to the drafting team and is thus integrally involved in report development. In addition, the lead editors are C·I·B Core Team Members (John Wilson, Tsungai Zengeya) and three are chapter lead authors (Brian van Wilgen, John Wilson, Tsungai Zengeya). Four team members (Charles Griffiths, Tammy Robinson, Nicola van Wilgen, Charlene Janion-Scheepers), and two alumni (Katelyn Faulkner, Clova Mabin) contributed to the report.

The triennial National Status Reports, by their nature, are static reports but the aim is to, over time, develop a dashboard of indicators to feed information on biological invasions through to policy-makers, managers, scientists, and the broader public. This will take time to develop, and refine, but over the coming few years the development team aims to make it increasingly easy to access data on biological invasions and to highlight management successes and areas where action needs to be prioritised. South Africa's National Status Report is unique in the world in focussing specifically on invasions and is an important part

1 Zengeya, T.A. and Wilson, J.R. (eds) 2020. The status of biological invasions and their management in South Africa in 2019. South African National Biodiversity Institute, Kirstenbosch and DSI-NRF Centre of Excellence for Invasion Biology, Stellenbosch, South Africa pp.71, DOI: 10.5281/zenodo.3947613.

of South Africa's global leading position on the issue (the government invests over ZAR 1 billion per year in an attempt to deal with the problem).

The report is based around a suite of indicators that provides details on: 1) how alien species are introduced and move around the country; 2) the status and impacts of 1880 alien species of which 776 are invasive; 3) the degree to which sites are invaded and impacted; and 4) the effectiveness of the full range of interventions that South Africa has used to address the problem. This report provides valuable insights into how South Africa can reduce the negative impacts of biological invasions on ecosystems, the economy, and people while retaining the benefits alien species provide where this is possible and desirable. It collates foundational information essential for researchers of the topic and provides an assessment of interventions that is vital for policy makers and managers.

5.3 Risk analysis

In September 2020, the Environmental Impact Classification for Alien Taxa (EICAT) was launched at the Neobiota conference as a global IUCN Standard, and the Standard document and Guidelines were published on the IUCN website. The work on EICAT had started in 2013 at a workshop organised by C•I•B core team member Sabrina Kumschick (then a Post-Doctoral Fellow). Since this workshop, some major steps have been taken in getting EICAT to where it is now, including the publication of improved guidelines and the application for various taxa.

The aim of EICAT is to give environmental managers, scientists and conservation practitioners, as well as the general public, a better understanding of the magnitude of impacts caused by alien (introduced, non-native) taxa. This can feed into policy making and the development of legislation, as well as aiding the prioritisation of management of alien taxa.

The EICAT Authority was formed to oversee the process and review EICAT assessments. It is chaired by C•I•B core team member Sabrina Kumschick and consists of several C•I•B associates and fellows (Sven Bacher, Piero Genovesi, Petr Pyšek, Tim Blackburn) and other international colleagues (Montserrat Vila, Sandro Bertolino, Helen Roy, Jonathan Jeschke, Tom Evans). Regular meetings are held by the EICAT Authority to ready assessments for publication on a database currently being developed by the IUCN ISSG (Invasive Species Specialist Group).

The Risk Analysis for Alien Taxa (RAAT) framework, which was developed by C•I•B core team members Sabrina Kumschick, John Wilson and Llewellyn Foxcroft is used to collate the evidence for the national regulation of alien taxa under the NEM: BA Alien and Invasive Species Regulations. In 2020 it was published in an international peer-reviewed journal (*NeoBiota*). Due to the pandemic, training courses had to be held online. Four training courses taught by

C•I•B core team member Sabrina Kumschick were held in 2020, of which two were full courses and two refresher courses, and 57 people were trained.

6 GOVERNANCE AND ORGANISATIONAL STRUCTURE

6.1 Steering Committee

Table 5. C·I·B Steering Committee members for 2020

Name	Affiliation	Role
Prof. Eugene Cloete	Chair of the Committee (outgoing); Vice Rector, Research, Innovation and Postgraduate Studies Stellenbosch University	Ex officio member
Prof. Louise Warnich	Dean of Science, Stellenbosch University	Ex officio member
Prof. Dave Richardson	Director, Centre for Invasion Biology, Faculty of Science, Stellenbosch University	Ex officio member
Dr Sarah Davies	Deputy Director: Operations, Centre for Invasion Biology, Stellenbosch University	Ex officio member
Prof. John Measey	Deputy Director: Science Strategy, Centre for Invasion Biology, Stellenbosch University	Ex officio member
Mr Nathan Sassman	Director: COE Programme, RCCE, National Research Foundation	NRF Representative
Prof. Michael Somers	Eugène Marais Chair of Wildlife Management, Mammal Research Institute, University of Pretoria	Core Team Representative
Prof. John Donaldson	Self employed	Industry Representative
Mr Michael Braack	Director, Biosecurity, Natural Resource Management Programme, Dept. Environment, Forestry and Fisheries	Industry Representative
Dr Angus Paterson	Managing Director, South African Institute for Aquatic Biodiversity	Industry Representative
Prof. Sheona Shackleton	Deputy Director, African Climate and Development Initiative (ACDI)	Industry Representative
Prof. Piero Genovesi	Director, ISPRA Institute for Environmental Protection and Research, Italy	International Science Advisor
Prof. Laura Meyerson	Professor, Department of Natural Resources Science, The University of Rhode Island, USA	International Science Advisor

6.2 Personnel involved in the COE

Table 6. 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
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

*Resigned in 2020

Table 7. 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
Prof. Patricia Holmes	Cape Ecological Services
Mr Brian Huntley	Private
Dr Michelle Jackson	Imperial College London, UK
Dr Charlene Janion-Scheepers	University of Cape Town
Dr Martine Jordaan	CapeNature

Full name	Affiliation
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
Dr Mlungele Nsikani	Scientist, Biological Invasions Directorate, SANBI
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

*Resigned in 2020

Table 8. C·I·B staff

Name	Institute	Position	Gender	Race
Mr Etienne Basson	SU	Iimbovane Outreach Assistant *	Male	Coloured
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 Suzaan Kritzinger-Klopper	SU	Chief Technical Officer	Female	White
Dr Sabrina Kumschick	SU	Researcher	Female	White
Ms Jean Lategan	SU	Personal Assistant #	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 Londiwe Msomi	SU	Education Outreach Officer	Female	African
Ms Erika Nortje	SU	Ecophysiology Lab Manager	Female	White
Prof. Dave Richardson	SU	Director	Male	White
Ms Mathilda Van Der Vyver	SU	Administrative Officer	Female	White
Prof. Brian Van Wilgen	SU	Research Professor	Male	White

#Position terminated during the year due to lack of funds

*Resigned during the year

Please see Appendix 1 for student and post-doc lists

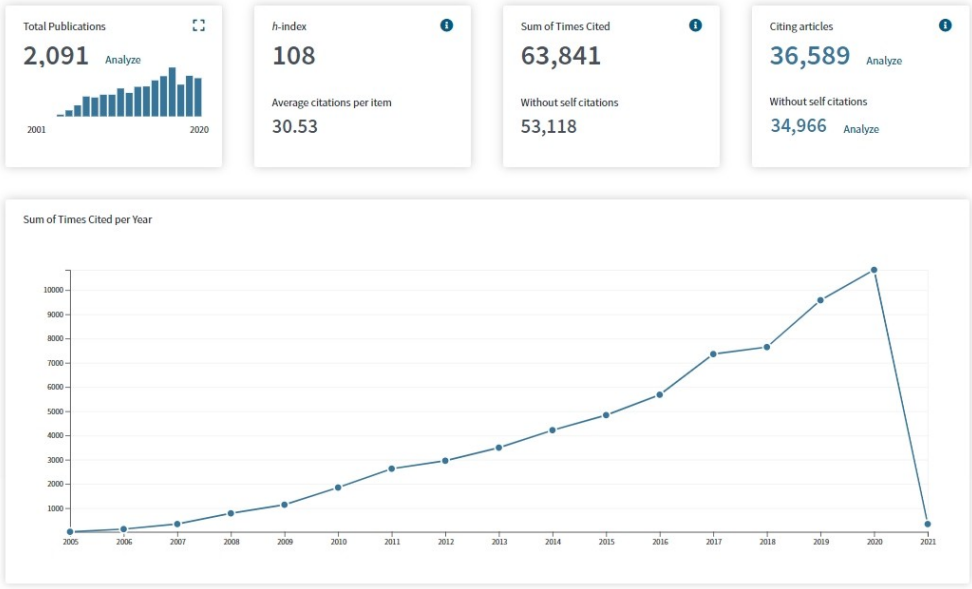
7 GENDER

Women form 25 % of the C•I•B's core team and 38% of our research associate network. All of the hub staff are women, and importantly, the all-woman limbovane team is a strong role model for inspiring secondary science learners to take up scientific careers. Our student body is 61% female, and 42% of our Post-Doctoral Fellows are women. The C•I•B makes every effort to provide an inclusive and friendly yet professional environment where all genders and cultural groups feel welcome and are given opportunities to be productive and grow.

8 RETURN ON INVESTMENT

The C•I•B published 183 papers in good quality peer-reviewed journals in 2020. This is huge return on investment for South Africa (funding from government was R7.5m, yielding R41k per publication unit).

8.1 Citation impact



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

9 THE FUTURE OF THE C·I·B

In early 2020 the C•I•B embarked on a process to determine options to ensure the sustainability of the Centre following the end of the DSI-NRF Centre of Excellence grant. At that stage, we had been assured that funding of the C•I•B (at 2019 levels) would be available until the end of the 2022/3 financial year. The

Centre successfully applied for a three year grant from Stellenbosch University's Strategic Fund for "Repositioning the Centre for Invasion Biology". Funds were allocated to support scoping meetings and partner workshops and for the appointment of a consultant to assist in identifying strategic options and potential funders for the Centre in the future. One major focus of the proposal was to secure four to five research chairs across several emerging or under-studied sub-fields of invasion science (agricultural economy, social science, risk management, biodiversity data science, global change, population modelling, economic modelling, restoration science, science engagement/outreach). The Strategic Fund proposal was presented to the Steering Committee and appears as an appendix to the 2020/1-2022/3 business plan of the COE since it now represents a parallel stream of work alongside the DSI-NRF grant.

The first event in the strategic repositioning process was a scoping workshop held in Stellenbosch and attended by selected C·I·B staff, core team members and key external players whose ideas on potential directions and funding options were considered valuable. The workshop was facilitated by Ms Tanja Hitchert of Hichert & Associates (Pty) Ltd, an expert in scenario planning, horizon scanning, risk scenarios and futures research. The participants explored issues pertaining to potential funding sources and models, possible institutional homes, focus areas of the C•I•B, leadership and other human capital, changing models of student funding, dependence on government funding, and changing views of biological invasions and other facets of global change among stakeholders. We explored the historical, contextual and transactional environments in which the C•I•B operates; forces for and against the C•I•B, key knowns and unknowns. These discussions led to the construction of a 'gameboard' for the future C·I·B and four broad-brush scenarios shown on the cover of this report. We also used the Three Horizons Model to identify elements that it would be necessary to scale up or abandon in the search for a more sustainable future.

The main output of the strategic discussions in June and July 2020 was a list of 10 strategic actions that were agreed upon to steer the C·I·B's future. These actions pertained to, among other things: fund raising, strengthening ties with stakeholders, quantifying costs of invasion in South Africa, and options for strengthening the C·I·B's footprint in Africa. Further initiatives to build on the strategic actions developed in the June/July meeting were halted by the totally unexpected notice from the National Research Foundation in August 2020 that funding to the C•I•B had been cut by 50% (25% reduction in funding for 2020's costs and expenses already incurred; 50% reduction in 2021 and 75% reduction in 2022).

The notice of funding cuts necessitated a halt in implementation of the strategic process and the C·I·B unfortunately had to turn its attention to short-term restructuring in order to meet the budget deficit caused by non-payment of funds

in 2020 (the 2020 grant was paid in November 2020) and the immediate cut in funding. All C•I•B staff were involved in a retrenchment process which took place in October and November 2020, resulting in the termination of employment for two staff members and adjustments of conditions of employment for several others. Retrenchment procedures for several other staff members have been deferred until March 2021.

Together with the policy reversals of DSI-NRF on contractual funding to the C•I•B until the end of the 2022/3 financial year, COVID-19 restrictions also placed severe strain on the C•I•B's efforts to chart a course for a sustainable future during 2020. Considerable efforts were made late in the year to attract funding from sources outside government and the academic sector. A substantial grant was received from the Millennium Trust in December 2020 and expressions of interest were received from several other sources and will receive attention in 2021.

A second workshop, with the aim of testing the ideas developed at the March 2020 workshop with the entire C·I·B team and partners, was planned for 15 and 16 March 2020, and had to be cancelled due to the COVID-19 lockdown. Instead, a series of eight online sessions were convened in June and July 2020, again facilitated by Tanja Hichert and a team of C·I·B members.

10 CONCLUSION

2021 promises many challenges. These include dealing with the severe disruptions to many C•I•B operations due to Covid-19 restrictions and the 50% cut in our funding. On top of these, and with less than two years of any funding from government left, the NRF has imposed additional compliance tasks, expectations, and levels of oversight on the COE. Much energy has been expended on refitting the C•I•B to be in a position to tackle the targets set for us

and we will strive to maintain the Centre's proud reputation in providing world-class training and research to meet the needs of South Africa. However, the tasks that lie ahead are daunting.

11 STAGE PROGRESS AGAINST SLA

A new Service Level Agreement (SLA) for the period 2020-2022 was agreed in December 2020, following discussion at the Steering Committee meeting on 27 November 2020. This SLA allows for the winding down of the DSI-NRF involvement during the period 2020-2022.

Target	2020 achievement
Governance:	
Two Steering Committee (virtual or real) meetings should take place per annum	Meetings took place on 26 March and 26 November (online via MS Teams)
Student nominations submitted to the NRF's student database	Nominations were completed in July 2020 (when grant no. 41313 was activated)
Annual Progress Reporting on all activities undertaken during the year for review by the Steering Committee	The online APR is complete and draft Annual Report will be tabled at the Steering Committee meeting on 25 March 2021.
Research:	
Peer-reviewed research papers published	183
Peer-reviewed papers with IF > 15 published	0
Peer-reviewed papers with IF > 4 published	33
Education and training:	
Honours students graduated	6
Masters students graduated	5
PhD students graduated	1
Post-Doctoral Fellows completed	3
Female students supported	72%
Black students supported	76%
95% SA students permanent residents and citizens, of which Black 90%, White 10%, Disabled 1%	100% South African
Post docs / ECR as proportion of supported researchers	14%
Honours students graduated	6
Networking:	
The CoE will publish vignettes of information on its website and provide these to the NRF	Nuggets sent to NRF 15 July 2020, 27 January 2021
Co-host SARChI Chair in Biodiversity Value and Change in the Vhembe Biosphere Reserve	CTM Prof. Peter Taylor is to vacate the Chair and move to another university

Target	2020 achievement
Memoranda of Understanding with key regional, national and international partners	Maintained MOUs with important partners
Joint supervision of students outside the core team and at other universities	13
Maintain a network of actively engaged Research Associates	15 Research Associate-led papers (target 10-20)
National conference attendance	6
International conference attendance	19
National conference/workshop organization	0
International conference/workshop organized	0
*due to COVID-19 induced lockdown during the first half of 2020.	
Information brokerage:	
Maintain an Information Retrieval and Submission System (IRSS) that curates the outputs of the Centre	IRSS is up to date and fully functional
Social media engagements with partners and interested parties (DSI-NRF branding)	Active profiles on two social media platforms (Facebook, Twitter)
Iimbovane outreach activities continue in 20 schools	20 schools
Classroom and field-based lessons presented at schools	11
Number of learners participating in the Iimbovane Outreach Project	331
News interest in both print and online media	76
Popular articles and talks in both print and online media	21
Service provision:	
Rating and scientific reviews for the NRF	31
Peer evaluations for national and international grant-making bodies	15
Participation in international science organizations	20
Journal editorships (editor, associate editor or editorial board membership)	37
Reviewing activities for national and international journals.	92
Inputs to policy relevant processes and documents	3 (EICAT; NSR; IPBES)

Appendix 1. Centre for Invasion Biology Outputs (2020)

Research

Books

Downs, C.T. and Hart, L.A. (eds)(2020). *Invasive Birds: Global Trends and Impacts*. CABI, Wallingford, UK. 381 pp, ISBN: 978-1-789-242065.

Traveset, A. and Richardson, D.M. (eds)(2020). *Plant Invasions: The Role of Biotic Interactions*. CABI, Wallingford, UK. 480 pp, ISBN: 978-1-789-242171.

van Wilgen, B., Measey, J., Richardson, D.M., Wilson, J.R. and Zengeya, T.A. (eds) (2020). *Biological Invasions in South Africa*. Springer International Publishing, Switzerland. 975 pp, ISBN: 978-3-030-32394-3.

Book chapters

Afonso, L., Esler, K.J., Geerts, S. and Gaertner, M. (2020). Comparing invasive alien plant community composition between urban, peri-urban and rural areas; the City of Cape Town as a case study. In: *Urban Ecology: Emerging Patterns and Social-Ecological Systems.* Verma, P., Singh, P., Singh, R. and Raghubanshi, A.S. (eds.). Elsevier, International. pp. 221-236. DOI: 10.1016/B978-0-12-820730-7.00013-6.

Baltzinger, C., Shukla, U., Msweli, L.S. and Downs, C.T. (2020). Ungulates as dispersal vectors of non-native plants. In: *Plant invasions: the role of biotic interactions.* Traveset, A. and Richardson, D.M. (eds.). CABI, Wallingford. pp. 105-137. DOI: 10.1079/9781789242171.0006.

Burnett, M. and Downs, C.T. (2020). Warbling White-eye (*Zosterops japonicus* Temminck and Schlegel 1845). In: *Invasive birds: global trends and impacts.* Downs, C.T. and Hart, L.A. (eds.). CABI, Wallingford, UK. pp. 170-174. DOI: 10.1079/9781789242065.0023.

Byrne, M.J., du Plessis, D., Ivey, P.J., Measey, J., Robertson, M.P., Robinson, T.B. and Weaver, K.N. (2020). Education, training and capacity-building in the field of biological invasions in South Africa. In: *Biological Invasions in South Africa.* van Wilgen, B.W., Measey, J., Richardson, D.M., Wilson, J.R. and Zengeya, T.A. (eds.). Springer, Cham. pp. 731-755. DOI: 10.1007/978-3-030-32394-3_25.

Cele, J. and Downs, C.T. (2020). Cattle Egret (*Bubulcus ibis* Linnaeus, 1758). In: *Invasive birds: global trends and impacts.* Downs, C.T. and Hart, L.A. (eds.). CABI, Wallingford, UK. pp. 138-143. DOI: 10.1079/9781789242065.0017.

Davies, S.J., Jordaan, M., Karsten, M., Terblanche, J.S., Turner, A.A., van Wilgen, B.W., Veldtman, R., Zengeya, T.A. and Measey, J. (2020). Experience and lessons from invasive and alien animal control projects carried out in South Africa. In: *Biological Invasions in South Africa.* van Wilgen, B.W., Measey, J., Richardson, D.M., Wilson, J.R. and Zengeya, T.A. (eds.). Springer, Cham. pp. 629-663. DOI: 10.1007/978-3-030-32394-3_22.

Ehlers Smith, D.A., Ehlers Smith, Y.C. and Downs, C.T. (2020). Continental analysis of invasive birds: Australia and New Zealand. In: *Invasive birds: global trends and impacts.* Downs, C.T. and Hart, L.A. (eds.). CABI, Wallingford, UK. pp. 258-265. DOI: 10.1079/9781789242065.0036.

Faulkner, K.T., Burness, A., Byrne, M.J., Kumschick, S., Peters, K., Robertson, M.P., Saccaggi, D.L., Weyl, O.L.F. and Williams, V. (2020). South Africa's Pathways of Introduction and Dispersal and How They Have Changed Over

Time. In: *Biological Invasions in South Africa.* van Wilgen, B.W., Measey, J., Richardson, D.M., Wilson, J.R. and Zengeya, T.A. (eds.). Springer, Cham. pp. 313-354. DOI: 10.1007/978-3-030-32394-3_12.

Foxcroft, L.C., van Wilgen, B.W., Abrahams, B., Esler, K.J. and Wannenburgh, A. (2020). Knowing-doing continuum or knowing-doing gap? Information flow between researchers and managers of biological invasions in South Africa. In: *Biological Invasions in South Africa.* van Wilgen, B.W., Measey, J., Richardson, D.M., Wilson, J.R. and Zengeya, T.A. (eds.). Springer, Cham. pp. 831-853. DOI: 10.1007/978-3-030-32394-3_28.

Hart, L.A. and Downs, C.T. (2020). Conclusions. In: *Invasive birds: global trends and impacts.* Downs, C.T. and Hart, L.A. (eds.). CABI, Wallingford, UK. pp. 369-371. DOI: 10.1079/9781789242065.0045.

Hart, L.A. and Downs, C.T. (2020). Continental analysis of invasive birds: Africa. In: *Invasive birds: global trends and impacts.* Downs, C.T. and Hart, L.A. (eds.). CABI, Wallingford, UK. pp. 265-278. DOI: 10.1079/9781789242065.0037.

Hart, L.A. and Downs, C.T. (2020). Greylag Goose (*Anser anser* Linnaeus, 1758). In: *Invasive birds: global trends and impacts.* Downs, C.T. and Hart, L.A. (eds.). CABI, Wallingford, UK. pp. 213-222. DOI: 10.1079/9781789242065.0029.

Hart, L.A. and Downs, C.T. (2020). Introduction. In: *Invasive birds: global trends and impacts.* Downs, C.T. and Hart, L.A. (eds.). CABI, Wallingford, UK. pp. 1-8. DOI: 10.1079/9781789242065.0001.

Holmes, P.M., Esler, K.J., Gaertner, M., Geerts, S., Hall, S.A., Nsikani, M.M., Richardson, D.M. and Ruwanza, S. (2020). Biological Invasions and Ecological Restoration in South Africa. In: *Biological Invasions in South Africa.* van Wilgen, B.W., Measey, J., Richardson, D.M., Wilson, J.R. and Zengeya, T.A. (eds.). Springer, Cham. pp. 665-700. DOI: 10.1007/978-3-030-32394-3_23.

Hui, C., Landi, P. and Latombe, G. (2020). The role of biotic interactions in invasion ecology: theories and hypotheses. In: *Plant invasions: the role of biotic interactions.* Traveset, A. and Richardson, D.M. (eds.). CABI, Wallingford, UK. pp. 26-44.

Kumschick, S., Foxcroft, L.C. and Wilson, J.R. (2020). Analysing the Risks Posed by Biological Invasions to South Africa. In: *Biological Invasions in South Africa.* van Wilgen, B.W., Measey, J., Richardson, D.M., Wilson, J.R. and Zengeya, T.A. (eds.). Springer, Cham. pp. 573-595. DOI: 10.1007/978-3-030-32394-3_20.

Le Roux, J.J., Clusella-Trullas, S., Mokotjomela, T.M., Mairal, M., Richardson, D.M., Skein, L., Wilson, J.R., Weyl, O.L.F. and Geerts, S. (2020). Biotic Interactions as Mediators of Biological Invasions: Insights from South Africa. In: *Biological Invasions in South Africa.* van Wilgen, B.W., Measey, J., Richardson, D.M., Wilson, J.R. and Zengeya, T.A. (eds.). Springer, Cham. pp. 387-427. DOI: 10.1007/978-3-030-32394-3_14.

Loureiro, T.G. (2020). Non-Indigenous Crayfish Species: A Global Assessment and Future Perspectives. In: *Crayfish: Evolution, Habitat and Conservation Strategies.* Ribeiro, F.B. (ed.). Nova Science Publishers, Incorporated, New York. pp. 105-136.

Maligana, N., Shivambu, C.T. and Downs, C.T. (2020). Chukar Partridge (*Alectoris chukar* Gray, 1830). In: *Invasive birds: global trends and impacts.* Downs, C.T. and Hart, L.A. (eds.). CABI, Wallingford, UK. pp. 132-137. DOI: 10.1079/9781789242065.0016.

Maligana, N., Shivambu, C.T. and Downs, C.T. (2020). Rock Dove (*Columba livia* Gmelin, 1789). In: *Invasive birds: global trends and impacts.* Downs, C.T. and Hart, L.A. (eds.). CABI, Wallingford, UK. pp. 109-117. DOI: 10.1079/9781789242065.0014.

Potgieter, L.J., Douwes, E., Gaertner, M., Measey, J., Paap, T. and Richardson, D.M. (2020). Biological Invasions in South Africa's Urban Ecosystems: Patterns, Processes, Impacts, and Management. In: *Biological Invasions in South Africa.* van Wilgen, B.W., Measey, J., Richardson, D.M., Wilson, J.R. and Zengeya, T.A. (eds.). Springer, Cham. pp. 275-309. DOI: 10.1007/978-3-030-32394-3_11.

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Products, artefacts and patents

None

Conferences attended

International plenary/keynote addresses

None

National plenary/keynote addresses

None

International oral contributions

Anders, M. Osten, A., Grass, I., Linden, V., Taylor, P. and Westphal, C. Biological pest control and pollination in macadamia orchards Effects of landscape composition and climatic gradients. Second Annual Workshop of South African Living Landscapes Network, Online, September 2020 (Taylor)

Bitani, N. Downs, C.T. 2020. Dispersal of invasive *Lantana camara* by native bird species in KwaZulu-Natal, South Africa. Seed Dispersal in the Anthropocene: 7th International Symposium on Frugivores and Seed Dispersal, Corbett Landscape, India, 2-6 March 2020 (Downs)

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Downs, C.T., Molefe, L., Tedder, M., Thabethe, V., Rushworth, I., 2020. Role of native avian frugivores in germination facilitation and potential dispersal of invasive American bramble (*Rubus cuneifolius*) in South Africa. Seed Dispersal in the Anthropocene: 7th International Symposium on Frugivores and Seed Dispersal, Corbett Landscape, India, 2-6 March 2020 (Downs)

Foxcroft, L.C., Moodley, D., Pyšek, P., Hejda, M., Čuda, J., MacFadyen, M., Pyšková, K. 2020. Alien plants in Kruger National Park: invasiveness as a basis for management intervention. 18th KNP International Savanna Science Network Meeting, March 2020 (Foxcroft)

Kruger, N., Herrel, A., Secondi, J. Measey, J. 2020. Invasive clawed frog, *Xenopus laevis*, can identify local predators regardless of coexistence time. 7th Annual Meeting of the Canadian Herpetological Society, Online, September 2020 (Measey)

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Novoa, A., Foxcroft, L.C., Keet, J-H., Pyšek, P., Le Roux, J.J. 2020. Islands of fertility promote the invasion of Opuntia stricta in Kruger National Park. NEOBIOTA2020, 11th International Conference on Biological Invasions, September 2020 (Foxcroft)

Pyšková, K., MacFadyen, S., Foxcroft, L., Hejda, M, Storch, D., Tropek, R., Pyšek, P. 2020. Diversity and distribution of mammals in dominant habitats of the Kruger National Park: a camera trap study. 18th KNP International Savanna Science Network Meeting, March 2020 (Foxcroft)

Pyšková, K., Foxcroft, L.C., Pyšek, P. 2020. Early stages of the common myna (Acridotheres tristis) invasion in Kruger National Park. NEOBIOTA2020, 11th International Conference on Biological Invasions, September 2020 (Foxcroft)

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Shikwambana, P., Taylor, J.C., Foxcroft, L.C., Bouwman, H., Vester, C. 2020. The iconic Kruger National Park: unspared from riverine microplastic pollution. 18th KNP International Savanna Science Network Meeting, March 2020 (Foxcroft)

Shivambu, T.C., Shivambu, N., Downs, C.T. 2020. Feeding biology of invasive rose-ringed parakeets Psittacula krameri in urban landscapes of eThekwini Metropole, KwaZulu-Natal Province, South Africa. Seed Dispersal in the Anthropocene: 7th International Symposium on Frugivores and Seed Dispersal, Corbett Landscape, India, 2-6 March 2020 (Downs)

Smith, K., Venter, J.A., Keith, M, Somers, M.J. Playing it safe or flirting with danger? How carnivore species use space and time to coexist within three South African protected areas. Australian Wildlife Management Association, 33rd Annual Conference. Online, December 2020. (Somers)

South, J. 2020. The pan-African crayfish hunt: Impact, implications and management of the Upper Zambezi crayfish invasion. University of Newcastle Modelling, Evidence and Policy Group 2020. (Presentation used as online teaching material), University of Newcastle, UK, June 2020 (Weyl)

South, J. 2020. The pan-African crayfish hunt: Impact, implications and management of the Upper Zambezi crayfish invasion. University of Essex, UK, March 2020 (Weyl)

Thabethe, V., Wilson, A.L., Hart, L., Downs, C.T. 2020. Ingestion by an invasive parakeet species reduces germination success of invasive alien plants relative to ingestion by indigenous turaco species in South Africa. Seed Dispersal in the Anthropocene: 7th International Symposium on Frugivores and Seed Dispersal, Corbett Landscape, India, 2-6 March 2020 (Downs)

Tye, D., Govender, D., Foxcroft, L.C., Nupen, L. 2020. Drivers of population dynamics in an invasive parthenogenetic snail in southern Kruger National Park. 18th KNP International Savanna Science Network Meeting, March 2020 (Foxcroft)

National oral contributions

Adams, L.D., Martin, G., Clark, V.R., Thabethe, V., Downs, C.T., Raji, A. Steenhuisen, S. 2020. The passage-through-gut effect of avian dispersers on the germination rate of an invasive alien plant Pyracantha angustifolia. South African Association of Botanists Conference, January 2020 (Downs)

Bitani, N., Ehlers Smith, D., Ehlers Smith, Y., Downs, C.T. 2020. Functional traits vary among fleshy-fruited invasive plant species and their potential avian dispersers. The Conservation Symposium, Online, November 2020 (Downs)

Canavan, S., Richardson, D.M., Le Roux, J.J. & Wilson, J.R.U. The introduction status of alien bamboos in South Africa Annual conference of the South African Association of Botanists, University of the Free State, QwaQwa campus, January 2020 (Richardson)

Clusella-Trullas S. 2020. Exploring behavioural thermoregulation as a key moderator of climate change impacts. Invited seminar (online), Dept. of Zoology and Entomology, University of Pretoria. Oct. 2020 (Clusella-Trullas)

Purdon, J., Pienaar, M., Shabangu, F.W., Somers, M.J., Findlay, K. Modelled sound exposure levels for marine fauna encountered during a seismic survey in Algoa Bay, South Africa. 2nd African Bioacoustics Community Conference, Online, Nov 2020 (Somers)

Van Zitters, M., Esler, K.J., Rebelo, A., Mingo, J. 2020. Making the case for active riparian rehabilitation. A comparison of methods in the Berg-Breede Catchment, Western Cape. 42nd Fynbos Forum (Virtual Event). 9-11 September (Esler)

International posters

Poongavanan, J., Altwegg, R., Durbach, I. Measey, J. 2020 Modelling the range-wide density patterns of the *Arthroleptella lightfooti* using acoustic monitoring data. International Statistical Ecology Conference (virtual): June 2020 (Measey)

National posters

None.

Education and training

Students supported by the Centre in 2020

Name	Citizenship	Institution	Race	Gender	Status	Funding level [2]
BSc (Honours)/4th year B. Agric.						
Mr Armand Engelbrecht	South Africa	University of Pretoria	White	M	Completed	Full
Ms Cally Jansen	South Africa	Stellenbosch University	Coloured	F	Completed	Full
Ms Vanessa Lauchande	South Africa	University of KwaZulu-Natal	Coloured	F	Completed	Full
Ms Megan Maroen	South Africa	Stellenbosch University	Coloured	F	Completed	Partial
Ms Jabulile Mzizi	South Africa	University of Pretoria	Black	F	Completed	Full
Ms Emily Rippon	South Africa	University of South Africa	White	F	Completed	Independent
Ms Ntombizanele Tshali	South Africa	South African Institute for Aquatic Biodiversity	Black	F	Completed	Full
Mr Dan Van Blerk	South Africa	Stellenbosch University	White	M	Completed	Independent
Masters						
Mr Lehlohonolo Donald Adams	South Africa	University of the Free State	Black	M	Completed	Independent
Mr Luca Afonso	South Africa	Stellenbosch University	White	M	Continuing	Independent
Ms Ashleigh Basel	South Africa	Stellenbosch University	White	F	Completed	Independent

2 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).

Name	Citizenship	Institution	Race	Gender	Status	Funding level
Ms Kiosha Bhikraj	South Africa	University of KwaZulu-Natal	Indian	F	Continuing	Independent
Mr Kyle Boast	South Africa	Stellenbosch University	White	M	Continuing	Independent
Ms Lee-Anne Botha	South Africa	University of Pretoria	Coloured	F	Continuing	Partial
Ms Amy Collop	South Africa	Stellenbosch University	Coloured	F	Continuing	Full
Ms Aneesa Du Plessis	South Africa	Cape Peninsula University of Technology	Coloured	F	Continuing	Full
Ms Melissa Ewels-Bezuidenhout	South Africa	Stellenbosch University	White	F	Completed	Independent
Ms Aviwe Homani	South Africa	Stellenbosch University	Black	F	Continuing	Partial
Ms Nolwethu Jubase	South Africa	Stellenbosch University	Black	F	Completed	Independent
Mr Tshililo Kharivha	South Africa	Rhodes University	Black	M	Continuing	Full
Mr Tevan William Key Lehman	South Africa	Stellenbosch University	White	M	Continuing	Independent
Ms Thandeka Mahlobo	South Africa	University of KwaZulu-Natal	Black	F	Continuing	Full
Mr Asekho Mantintsilili	South Africa	University of KwaZulu-Natal	Black	M	Continuing	Full
Ms Chelsey Matthys	South Africa	Cape Peninsula University of Technology	Coloured	F	Continuing	Independent
Ms Ncumisa Matam	South Africa	Rhodes University	Black	F	Continuing	Independent
Ms Sinenhlahla Mntambo	South Africa	University of KwaZulu-Natal	Black	F	Completed	Independent
Mr Peter Mochechela	South Africa	University of Fort Hare	Black	M	Continuing	Independent

Name	Citizenship	Institution	Race	Gender	Status	Funding level
Ms Lucia Mokubedi	South Africa	University of Cape Town	Black	F	Completed	Independent
Ms Lindelwa Msweli	South Africa	University of KwaZulu-Natal	Black	F	Completed	Partial
Mr Bhongolethu Mtengwana	South Africa	University of the Western Cape	Black	M	Completed	Full
Ms Jeanne Mukarugwiro	Rwanda	University of Witwatersrand	Black	F	Completed	Independent
Mr Nkosinathi Ntuli	South Africa	Nelson Mandela University	Black	M	Continuing	Independent
Mr Samuel Peta	South Africa	Stellenbosch University	Black	M	Continuing	Full
Mr Asive Qikwa	South Africa	Stellenbosch University	Black	M	Continuing	Independent
Ms Mancha Ramotjiki	South African	University of Venda	Black	F	Completed	Partial
Mr Tshepiso Seboko	South Africa	Rhodes University	Black	M	Continuing	Full
Ms Thembeka Thwala	South Africa	University of Venda	Black	F	Continuing	Independent
Ms Monique Van Zitters	South Africa	Stellenbosch University	Coloured	F	Continuing	Partial
Ms Catherine Wagener	South Africa	Stellenbosch University	White	F	Completed	Full
Ms Staci Warrington	South Africa	Stellenbosch University	White	F	Completed	Independent
PhD-Upgrade						
Ms Nicole Vorster-Martin	South Africa	Stellenbosch University	White	F	Continuing	Full
Ms Anneke Schoeman	South Africa	University of the North West	White	F	Continuing	Full
PhD						
Mr Brent Abrahams	South	Stellenbosch University	Coloured	M	Continuing	Independent

Name	Citizenship	Institution	Race	Gender	Status	Funding level
	Africa					
Ms Uviwe Bolosha	South Africa	Rhodes University	Black	F	Continuing	Full
Ms Henrika Bosua	South Africa	Stellenbosch University	White	F	Continuing	Full
Ms Dewidine van der Colff	South Africa	South African National Biodiversity Institute	Coloured	F	Continuing	Independent
Mr Blair Cowie	South Africa	University of Witwatersrand	White	M	Completed	Independent
Ms Patricia Duncan	South Africa	Stellenbosch University	White	F	Continuing	Independent
Ms Emily Jones	South Africa	Nelson Mandela University	White	F	Continuing	Full
Mr Dumisani Khosa	South Africa	Rhodes University	Black	M	Completed	Independent
Ms Natasha Kruger	South African	Stellenbosch University	White	F	Completed	Partial
Ms Lerato Maimela	South Africa	University of Pretoria	Black	F	Continuing	Independent
Ms Ndivhuwo Maligana-Shivambu	South Africa	University of KwaZulu-Natal	Black	F	Continuing	Partial
Mr Anthony Mapaura	Zimbabwe	University of the Free State	Black	M	Continuing	Partial
Mr Phikolomzi Matikinca	South Africa	Stellenbosch University	Black	M	Continuing	Independent
Ms Tumeka Mbobo	South Africa	Stellenbosch University	Black	F	Continuing	Independent
Mr Siphosenkosi Mbonani	South Africa	University of Witwatersrand	Black	M	Continuing	Full
Mr Phuluso Mudau	South Africa	University of Witwatersrand	Black	M	Continuing	Full
Mr Takalani Nelufule	South Africa	University of Pretoria	Black	M	Continuing	Independent

Name	Citizenship	Institution	Race	Gender	Status	Funding level
Ms Duduzile Ngwenya	Zimbabwe	Stellenbosch University	Black	F	Continuing	Independent
Ms Sinazo Ntsonge	South Africa	Rhodes University	Black	F	Continuing	Full
Mr Beka Nxele	South Africa	Stellenbosch University	Black	M	Continuing	Independent
Ms Mmatsawela Ramahlo	South Africa	University of Pretoria	Black	F	Continuing	Full
Ms Davina Saccaggi	South Africa	Stellenbosch University	White	F	Continuing	Independent
Mr Cavin Shivambu	South Africa	University of KwaZulu-Natal	Black	M	Continuing	Partial
Ms Alekzandra Szewczuk	South Africa	University of Witwatersrand	White	F	Continuing	Full
Mr Thozamile Yapi	South Africa	Rhodes University	Black	M	Continuing	Independent

Post-Doctoral Fellows supported in 2020

Name	Citizenship	Institution	Race	Gender	Status	Funding [2]
Dr James Baxter-Gilbert	Canada	Stellenbosch University	White	M	Continuing	Full
Dr Anandi Bierman	South Africa	Stellenbosch University	White	F	Continuing	Full
Dr Arunava Datta	India	Stellenbosch University	Indian	M	Resigned	Independent
Dr Tainã Gonçalves Loureiro	Brazil	Stellenbosch University	White	F	Complete	Full
Dr Heidi Hirsch	Germany	Stellenbosch University	White	F	Complete	Partial
Dr Jan-Hendrik Keet	South Africa	Stellenbosch University	White	M	Complete	Full
Dr Mlungele Nsikani	Zimbabwe	Stellenbosch University	Black	M	Resigned	Full
Dr Josie South	United Kingdom	South African Institute for Aquatic Biodiversity	Coloured	F	Continuing	Full
Dr Quentin Willot	Belgium	Stellenbosch University	White	M	Complete	Independent

Networking

Academic visitors to core team members

Prof. Petr Pyšek, The Czech Academy of Sciences, Department of Invasion Ecology. Collaborator on maintaining functionality of savanna ecosystems in Kruger National Park (Foxcroft)

Dr Anandi Bierman, Department of Conservation Ecology and Entomology, Stellenbosch University, Polyphagous Shothole Borer Beetle sampling visit, Free State National Botanical Garden (Mokotjomela)

Academic visits by core team members to other institutions

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 Llewellyn Foxcroft, SANPARKS; Dr Ana Novoa, Department of Invasion Ecology, The Czech Academy of Sciences, Czech Republic (Foord)

Awards to core team members

None

Research collaborations

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

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

Assessing priorities for invasion science in the Anthropocene. Collaborator: Prof. Tony Ricciardi, Redpath Museum, McGill University, Canada (Richardson)

Assessing the potential of genome size as an indicator of invasiveness in Cactaceae. Collaborator: Prof. João Loureiro, Centre for Functional Ecology, Department of Life Sciences, University of Coimbra, Portugal (Richardson)

Assessing water use of *Eucalyptus* species in native and planted forests. Collaborators: Prof. Christian Kull, Institute de Géographie et Durabilité, Faculté des Géosciences et de L'environnement, Université de Lausanne, Switzerland; Prof. Rodney Keenen, School of Ecosystem and Forest Sciences, University of Melbourne, Australia (Richardson)

Beneficial impact of alien taxa classification. Collaborators: Giovanni Vimercati, Department of Biology, Unit Ecology & Evolution, University of Fribourg, Switzerland; Sven Bacher, Department of Biology, Unit Ecology & Evolution, University of Fribourg, Switzerland; Lara Volery, Department of Biology, Unit Ecology & Evolution, University of Fribourg, Switzerland; Anna Probert, Department of Biology, Unit Ecology & Evolution, University of Fribourg, Switzerland (Kumschick)

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)

Blaauwberg Sand Fynbos Restoration Project, The. Collaborators: Pat Holmes (SU); City of Cape Town, with funding Hans-Hoheisen Charitable Trust (Esler)

Carnivores and people, 2017-2020. 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)

Conservation monitoring of otters in South Africa, 2014-2020. Collaborator: Trevor McIntyre, University of South Africa (Somers)

Ecologically-based management of pest rodents. Collaborators, Dr Lourens Swanepoel, University of Venda, Steven Belmain, University of Greenwich, UK, Apia Massawe, Sekoine University of Agriculture, Morogoro, Tanzania (Taylor)

Effects of invasive Parthenium hysterophorus on native plant establishment, soil characteristics and soil enzymatic activities as indicators of impacts in Kruger National Park. Collaborators: Prof. Stefan Foord, Department of Zoology, University of Venda, South Africa; Dr Ana Novoa, Department of Invasion Ecology, The Czech Academy of Sciences, Czech Republic (Foxcroft)Seed-dispersal: Bramble. Collaborators: Dr I Rushworth, Ezemvelo KZN Wildlife, Pietermaritzburg; Dr M Tedder, University of KwaZulu-Natal, Pietermaritzburg campus (Downs)

Effects of land use and seasonal variation on small mammal species of the Magaliesburg biosphere, The. Collaborator: Andre Ganswindt, University of Pretoria (Somers)

EICAT assessment of alien insects in Australia: Melodie McGeoch, University of Melbourne, Australia; Helen Roy; Sandy Liebhold; Lori Lach; Myron Zalucki; Manu Saunders; David Yeates; Markus Riegler; Treena Burgess; Andrew Cox; Sarah Hilton; Dave Palmer; Carol Booth; Steven Chown; Chris McGrannachan; Sandra Parson; Rebecca O’Connor (Kumschick)

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

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-Institute of Freshwater Ecology and Inland Fisheries, Berlin, Germany.; Sven Bacher, Department of Biology, Unit Ecology & 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)

Environmental risk perceptions and public policy preferences for ornamental horticulture in Botswana, Namibia and South Africa. Collaborators: Jana Fried, Katharina Dehnen-Schmutz, Coventry University, UK (Wilson)

Foreign exploration for biological control agents for invasive alien *Tamarix*. Collaborator: Dr Masssimo Cristifaro, Accademia Nazionale Italiana di Entomologia, Italy: Tamarix Biocontrol (Byrne)

Frameworks for invasion science. Collaborators (see special issue of NeoBiota / attendees of workshop in 2019) (Wilson)

Global strategy for invasive alien trees, A. Collaborators: Giuseppe Brundu, Università di Sassari, Italy; Anibal Pauchard, University of Concepción, Chile; Petr Pyšek, Jan Pergl, Academy of Sciences of the Czech Republic; David M. Richardson, C·I·B, Stellenbosch University (Wilson)

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

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

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

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

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, 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. Dr Philipp Lehmann, Stockholm University, Sweden (Terblanche)

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

Invasive alien birds, CABI book on invasive alien birds globally. Collaborators: 80+ authors contributing to chapters (Downs)

Invasives aliens. Collaborators: Ezemvelo KZN Wildlife; Ethekwini Municipality (Downs)

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

Invasiveness of horticultural cultivars, The. Collaborators: Prof. Sjirk Geerts (CPUT); Dr S. Kumschick, SANBI/SU; Prof. Chris Daniels (CPUT); Mr Terence Mabela (Wilson)

Maintaining functionality of savanna ecosystems in Kruger National Park. Collaborator: Prof. Petr Pyšek, Department of Invasion Ecology, The Czech Academy of Sciences, Czech Republic (Foxcroft)

Marion Island *Mus musculus domesticus* ecology. Collaborator, Professor Peter le Roux and Dr Michelle Greve, Department of Plant and Soil Sciences. Collaborator, Dr Grant Hall, Mammal Research Institute (MRI), University of Pretoria (Chimimba)

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

Microsatellite transfer and genotyping of Australian acacias. Collaborators: Prof. Cristina Maguas, Centro de Estudos do Ambiente, Faculdade de Ciências, Universidade de Lisboa, Portugal; Prof. Jaco Le Roux, Department of Biological Sciences, Macquarie University, Australia (Richardson)

Modelling impacts of alien ecosystem engineers. Collaborators: South Africa: Dr Saachi Sadchatheeswaran; Prof. George Branch; Dr Lynne Shannon; Prof. Colleen Moloney, all University of Cape Town. Spain: Dr Marta Coll M (Robinson-Smythe)

Monitoring and post-release evaluation of biological control of alien invasive weeds. Prof. Martin Hill, CBC Rhodes University (Byrne)

Monitoring and post-release evaluation of biological control of alien invasive weeds. Prof. Ed Witkowski, School of APES, University of the Witwatersrand (Byrne)

Natural pest control of stink bugs in macadamia orchards. Collaborators: Prof. Catrin Westphal, University of Göttingen, Germany and Prof. Ingo Grass, University of Hohenheim, Germany (Taylor)

Non-native mycorrhizal fungi. Collaborators: Dr Marieka Gryznehout (UoFS); Ms Veronica Magagula (Wilson)

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

Plant invasions in Africa: a review. Prof. Petr Pyšek, Institute of Botany, Academy of Sciences of the Czech Republic; Dr Arne Witt, CABI (Richardson)

Plant invasions: the role of biotic interactions. Prof. Anna Traveset, Institut Mediterrani d'Estudis Avançats, Balearic Islands, Spain + 49 other collaborators (Richardson)

Polyphagous shothole borer – an economic assessment of impacts in South Africa. Prof. Martin de Wit, School of Public Leadership, Stellenbosch University; Dr James Blignaut, SAEON (Richardson).

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. (Terblanche)

Restore the Kuils River, revitalise its people. Collaborators: Prof. Martin de Wit, School of Public Leadership, Stellenbosch University; Dr James Blignaut, SAEON (Esler)

Screening and evaluation of agents for biological control of alien invasive cacti. Collaborator: Dr Arne Witt, CABI (Byrne)

Screening and evaluation of agents for biological control of alien invasive cacti. Collaborator: Prof. Iain Paterson, CBC, Rhodes University (Byrne)

Screening and evaluation of agents for biological control of invasive solanum in New Zealand. Collaborator: Dr Angela Bownes, New Zealand Landcare (Byrne)

Small carnivores in space and time, 2012-2020. Collaborators: Emmanuel do Linh San, University of Fort Hare; Jerry Balant, Mississippi State University, USA; Dr Jun Sato, Fukuyama University, Japan (Somers)

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

Socio-economic Benefits of Ecological Infrastructure (EI). Collaborators: Prof. Niels Fold & Dr Laura Vang Rasmussen, University of Copenhagen, Dept. of Geosciences and Natural Resource Management, Denmark; Prof. Mark New, Prof. Stephanie Midgely, Dr Petra Holden, Dr Nadine Methner, Prof. Sheona Shackleton, University of Cape Town, African Climate & Development Initiative; Dr Alanna Rebelo, Stellenbosch University, Dept. 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 & Evolution, University of Fribourg, Switzerland ; Lara Volery, Department of Biology, Unit Ecology & 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), 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 & Hydrology, UK; Wolf-Christian Saul, Freie Universitaet Berlin, Germany; Riccardo Scalera, IUCN/SSC Invasive Species Specialist Group, Italy (Kumschick)

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)

Soil microbiota associated with Australian acacias. Collaborators: Prof. Jaco Le Roux, Department of Biological Sciences, Macquarie University, Australia; Prof. A. Valverde, Instituto de Recursos Naturales y Agrobiología de Salamanca, Spain (Richardson)

Student apprenticeship- Prof. Martin Hill (Rhodes University) and others plus DEFF (Downs)

Testing geographic thermal acclimation of invasive species in native and invasive range. Collaborators: Prof. Robert Britton, University of Bournemouth, UK; and Prof. Anthony Ricciardi, McGill University, Canada, and Redpath- Post-doctoral research associate Dr Josie South visited Britton lab at U. Bournemouth (Weyl)

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

Towards a global strategy for the management of biological invasions. Collaborator: Prof. Laura Meyerson, Department of Natural Resources Science, University of Rhode Island, USA (Richardson)

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

Trees for climate change and agroforestry: towards sustainable planting strategies in Africa. Collaborators: Katharina Dehnen-Schmutz, Carlos Ferreira (Coventry University, UK). (Wilson)

Trends in the detection of aquatic non-indigenous species. Collaborators: USA: Prof. Jim Carlton (Williams College and Mystic seaport Museum) , Dr Gregory Ruiz (Smithsonian Institute), Dr John Darling (US Environmental Protection Agency), Dr Paul Fofonoff (Smithsonian Institute); Canada: Dr Sarah Bailey (Fisheries and Oceans), Dr Thomas Therriault (Fisheries and Oceans), Dr Farrah Chan (Fisheries and Oceans), Prof. Nicolas Mandrak (University of Toronto), Dr Cynthia McKenzie (Fisheries and Oceans); Australia: Prof. Marnie Campbell (Deakin University), Prof. Chad Hewitt (Murdoch University); Italy: Dr Agnes Marchini (Pavia University), Prof. Anna Occhipinti-Ambrogi (Pavia University); Israel: Dr Bella (The Steinhardt Museum of Natural History); Hawaii: Dr Inti Keith (Charles Darwin Foundation); Portugal: Dr Joao Canning-Clode (Agência Regional para o Desenvolvimento da Investigação Tecnologia e Inovação), Dr Nuno Castro (Agência Regional para o Desenvolvimento da Investigação Tecnologia e Inovação), Dr Paula Chainho (Universidade de Lisboa); Argentina: Dr Evangelina Schwindt (Instituto de Biología de Organismos Marinos); UK: Dr Lynsay Brown (Aberdeen University); Brazil: Prof. Joel Creed (Universidade do Estado do Rio de Janeiro), Dr Larissa Pires-Teixeira ((Universidade do Estado do Rio de Janeiro); France: Dr Amelia Curd (Centre Ifremer de Bretagne); Estonia: Dr Hen Ojaveer (University of Tartu); New Zealand: Prof. Graeme Inglis (National Institute of Water & Atmospheric Research), Dr Kimberley Seaward (National Institute of Water & Atmospheric Research); Ukraine: Dr Mikhail Son (National Academy of Sciences of Ukraine); and China: Dr Aibin Zhan (Chinese Academy of Sciences) (Robinson-Smythe)

Under-graduate vacation apprenticeship programme mainly focusing on biocontrol and so are working with Prof. Martin Hill (Rhodes), Dr Costas Zacharides (PPRI, Cedara), Dr Des Conlong (SASRI, Mt Edgecombe) and Dr T Olckers (UKZN) (Downs)

Understanding Echium invasion & 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)

Information brokerage

Popular articles

Botha, L. 2020. Bats: the answer to macadamia pests? Farmer's Weekly, 11 December 2020.

Duvenage, E. 2020. Gratis boek bied ensiklopediese kennis oor indringers in Suid-Afrika. Landbouweekblad, 16 Julie 2020.

Weier, S., Linden, V. & Taylor, P. 2020. Bats versus macadamia crop pests. Quest 16: 16-17.

Weyl, O.L.F. & group. Invasions Research News from South Africa from the Weyl-Lab. Pathways 23(2), 7-10. (Invasive and Introduced Species Section of the American Fisheries Society Newsletter).

Talks

Baxter-Gilbert, J. 2020. Presentation to Canadian Herpetological Society. Virtual, 12 September 2020.

Mokotjomela, T.M. 2020. Presentations on Management of Biological Invasions to Free State Provincial Department of Agriculture and Land Use. Premier Hotel, Bloemfontein, 27 November 2020.

Media interactions

Newspaper articles

Anoniem. Dié besies sal dalk nie kan aanpas. Die Burger (Oos-Kaap). 27 Mei 2020.

Anoniem. Dié liewenheerbesies se dae is dalk getel. Die Burger (Wes-Kaap). 27 Mei 2020.

Anoniem. Nuwe boek oor indringers kan wêreldwyd byval vind. Eikestadnuus. 11 June 2020.

Anoniem. Nuwe plan teen indringerspesies. Die Burger. 23 September 2020.

Anonymous. Tackling the silent invaders of our turf. The Witness. 8 June 2020.

Barnard, M. Verandering in klimaat gee dié indringer wind van voor. Beeld. 27 Mei 2020.

Ishmail, S. Framework to counter heritage site alien species. Cape Argus. 22 September 2020.

Staff reporter. Invasion of World Heritage Sites gives rise to new alien-detection framework. Cape Times. 22 September 2020.

Staff reporter. Invasive ladybird may not adapt to climate change. Cape Argus (Early). 26 May 2020.

Staff reporter. Invasive ladybird may not adapt to climate change. Cape Times. 28 May 2020.

Staff reporter. Size change in transplanted toads. The Star (Early Edition). 10 December 2020.

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Service provision

Panels and committees

International

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

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) – Invasive Alien Species Assessment. Lead Author (Foxcroft, Weyl); Coordinating Lead Author (Rahlao); Review Editor (Hui; Richardson; Wilson)

International Ornithological Congress: Fellow (Downs)

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

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

IUCN SSC - Conifers: Member (Richardson)

IUCN SSC - Crocodile Specialist Group: Member (Downs)

IUCN SSC - Hippo Specialist Group: Member (Downs)

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

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

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

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

IUCN SSC - Stork Specialist Group: Member (Downs)

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

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

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

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

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

National

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

Chair then Secretary (Wilson)

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

Fynbos Forum Committee: Member (Esler)

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

Mammal Research Institute, Advisory Board Member (Taylor)

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

SACNASP Qualifications Assessment Committee (Taylor)

SAIAB Advisory Board: Member (Griffiths)

SANBI Board member; and Chair of Research, development and innovation subcommittee (Van Wilgen)

WRC Reference Group: The use of long-term, large-scale data combined with historic ecological data to support reserve implementation: Member (Esler)

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 (Hui; Kumschick; Richardson)

Ecological Complexity (Hui)

Ecological Solutions and Evidence (Zengeya)

Ecography (Clusella-Trullas)

F1000 (Terblanche)

Forest Ecosystems (Richardson)

Frontiers in Ecology and Evolution (Hui)

Global Ecology and Biogeography (Hui)

Herpetological Conservation & Biology (Measey)

Ibis (Downs)

Koedoe (Robinson-Smythe; Somers)

Mammalian Biology (Somers)

NeoBiota (Foxcroft; Kumschick; Richardson; Wilson)

PeerJ (Measey)

Salamandra (Measey)

Urban Ecosystems (Downs)

Editorial Boards

Acta Chiropterologica, Editorial Board Member (Taylor)

African Entomology, Editorial Board member (Terblanche)

Animals, Editorial Board member (Griffiths)

AoB PLANTS, Editorial Board member (Richardson)

Journal of Insect Physiology, Editorial Board member (Terblanche)

Journal of Thermal Biology, Editorial Board member (Clusella-Trullas; Terblanche)

Koedoe, Editorial Board member (Griffiths)

Malagasy Nature, Editorial Board Member (Taylor)

Mammalia, Editorial Board Member (Taylor)

Nature Conservation Research (Somers)

Ostrich, Editorial Board member (Downs)

Russian Journal of Biological Invasions, Editorial Board member (Richardson)

Zookeys (Foord)

Reviewing

For national (SA) journals
African Entomology; Africa Journal of Aquatic Science; African Journal of Herpetology; African Journal of Marine Sciences; African Journal of Wildlife Research; African Zoology; Arachnology; Bothalia; Koedoe; Ostrich; South African Geographical Journal; South African Journal of Botany; South African Journal of Science

For international journals
Acta Chiropterologica; Acta Oecologia; African Geographic Review; African Journal of Ecology; African Journal of Range and Forage Science; American Naturalist; Animal Biodiversity; Austral Ecology; Austral Entomology; Behavioral Ecology; Biodiversity and Conservation; Biological Conservation; Biological Control; Biological Invasions; Biological Journal of the Linnean Society; Biology Open; Bothalia; BMC Infectious Diseases; Communications Biology; Conservation Biology; Conservation Science and Practice; Diversity; Ecography, Ecology and Biogeography ; Ecology; Ecology & Evolution; Ecology Letters; Ecological Entomology; Ecosystem Services; Environmental Conservation; Environmental Reviews; Evolutionary Ecology; Estuarine, Coastal and Shelf Science; Food and Energy Security; Forest Ecology and Management; Frontiers in Ecology and the Environment; Frontiers in Ecology and Evolution; Global Change Biology; Global Ecology & Conservation; Global Ecology and Biogeography; Helgoland Marine Research; Insects; Invasive Plant Science and Management; Journal of Animal Ecology; Journal of Applied Ecology; Journal of Environmental Management; Journal of Environmental Planning and Management; Journal of Experimental Biology; Journal of Experimental Marine Biology and Ecology; Journal of Insect Physiology; Journal of Thermal Biology; Journal of Vertebrate Biology; Journal of Zoology; Marine Biodiversity: Marine Biology Research; Marine Biological Invasions; Marine Ecology Progress Series; Marine Policy; Nature; Nature Communications; Nature Ecology & Evolution; Nature Scientific Reports; NeoBiota; Ocean and Coastal Management; Ornithology Research; PeerJ; Pest Management Science; Philosophical Transactions of the Royal Society B; Plant

Biology; PLoS ONE; Proceedings of the Royal Society of London B Biological Sciences; Restoration Ecology; Science; Science of the Total Environment; Scientific African; Scientific Reports; Sustainability Science; Web Ecology; Weed Research; and *Zoological Journal of the Linnean Society*

Grant reviews for external bodies

Austrian Science Fund- grant application (Wilson)

Biological Control Project Proposal, United States Department of Agriculture, Agriculture Research Service (USDA-ARS) (Byrne)

Czech Science Foundation (Richardson)

European Research Council (Hui)

French Polar Institute (IPEV) (Terblanche)

Leverhulme Trust, UK (Richardson)

National Environmental Research Council, UK- standard grant proposal (Richardson; Wilson)

National Geographic Advisory Board Member- CRE Reviewer Circle (Downs)

National Geographic Society (Somers)

Appointment reviews and committees

Rhodes University, South Africa: Associate Professorial Appointment (Byrne)

Rhodes University: Associate Professorial Appointment (Chimimba)

SANBI, Non-Detriment Finding committee for Serval (Somers)

University of Fribourg: Professorial Appointment (Richardson)

University of Pretoria, Extraordinary lecturer renewal of appointment (Zengeya)

NRF service provision

NRF rating and proposal reviews

Proposal review for research grants: General (5); Conservation and Management of Ecosystems and Biodiversity focus area (3); and Research Chair Application Assessment proposal review (2)

Rating reviews (13)

Thuthuka grant application (1)

NRF panel and committee service

O. Tambo NRF Chair Review Panel (1)

SARChI Chairs, Assessment panel for renewal applications (4)

NRF SARChI Five Year Evaluation (3)

Appendix 2. Audited financial statements