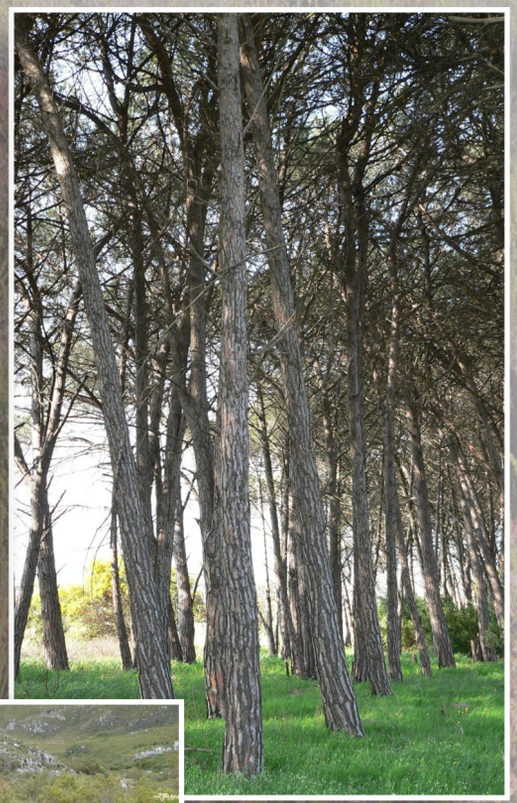
DST-NRF Centre of Excellence for Invasion Biology

Self-Evaluation Report



Director:
Prof. Steven L. Chown
Faculty of Science
Stellenbosch University
Private Bag X1
Matieland 7602
South Africa

Tel: +27 (0)21 808 2832
Fax: +27 (0)21 808 2995

UNIVERSITEIT·STELLENBOSCH·UNIVERSITY
jou kennisvennoot • your knowledge partner

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

science and technology
Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA

National Research Foundation
NRF

DST-NRF Centre of Excellence for Invasion Biology
Centres of Excellence Review
(1 June 2004 - 30 June 2008)

Reducing the rate and impacts of biological invasions
http://www.sun.ac.za/cib/2008Review/

Contents


Summary

The Centre for Invasion Biology (C·I·B) is an inter-disciplinary, inter-institutional Centre of Excellence (CoE) established within the DST-NRF Centres of Excellence Programme. It is co-funded principally by the South African Department of Science and Technology (DST), through the National Research Foundation (NRF), Stellenbosch University (SU), and more recently the South African Department of Water Affairs and Forestry's Working for Water (WfW) programme. The C·I·B was established *de novo* in June 2004 with the vision *'to provide the scientific understanding required to reduce the rate and impacts of biological invasions in a manner that will improve the quality of life of all South Africans'*. The C·I·B addresses five major Key Performance Areas: Research, Education and Training, Information Brokerage, Networking, and Service Provision. It presently comprises three full-time academic staff (including the Director), 16 additional core team members at a range of tertiary institutions and public entities, and 14 permanent and contract support staff. The long- and short-term research is built around six themes: Biodiversity Foundations, Large Scale Patterns in Biodiversity, Determinants of Invasion and Scenarios of Change, Interactions between Indigenous and Invasive Species, Impacts of Invasion, and Social Perceptions and Invasions.

Between June 2004 and June 2008, the C·I·B contributed 246 primary research outputs, including in the journals *Nature, Science, PLoS Biology,* and *Proceedings of the National Academy of Sciences of the U.S.A.* C·I·B members further contributed three books and 185 conference presentations, including international plenary and keynote addresses. This work has been rewarded, with, for example, Prof. David M. Richardson receiving the international, prestigious, Hans Sigrist Award, and an NRF A1 rating.

Over the period, 228 student and post-doc registrations were supported, with 90 black student and post-doc registrations and 129 registrations by women. Fifty-seven students have graduated or successfully completed their work (two Ph.D., 13 M.Sc., 24 Hons or 4th years, and 18 undergraduates). Forty-four students were co-supervised and an additional 30 students attended the Biodiversity Academy jointly held with the Birds as Keys to Biodiversity CoE. A further 3400 Grade 10 and 11 learners were introduced to Biodiversity science, and 193 teachers trained, via the Iimbovane Outreach Programme undertaken in collaboration with the Western Cape Education Department and co-funded via the University of Sheffield by the U.K. Darwin Initiative.

The C·I·B provides substantial service both domestically and abroad. Its most significant service locally has been the provision of expertise for the development of the regulations for Chapter 5 of the National Environmental Management: Biodiversity Act. Several staff have devoted significant time to the process over a period that has stretched from the inception of the C·I·B, and that has yet to be concluded. The regulations remain the subject of work and contention. Internationally, the C·I·B has not only contributed to the development of indicators for the 2010 Biodiversity Target, but has also had a significant profile via the provision of advice to the Antarctic Treaty System, through the service of the C·I·B Director to the Scientific Committee on Antarctic Research as its representative to the Committee for Environmental Protection.

As a central part of its activities, the C·I·B has entered into three international and five local formal agreements, including important collaborations with the Working for Water Programme and local conservation agencies. Further agreements are in development. These activities and the central grants from the DST-NRF and Stellenbosch University have resulted in a total funding award of R 41 246 403, of which R 12 981 658 has come from outside SU and the DST-NRF CoE programme, and of that R 7 490 799 exclusively from outside sources.

The next phase of the C·I·B's work will involve a redevelopment of its strategy further to focus on three major areas: Interactions among global change drivers, genetic tools to inform the science required to reduce the rates and impacts of biological invasions, and science in service of policy. Moreover, it will also focus on further ways to ensure the Centre's continuation beyond the 10 year lifespan originally envisaged in the CoE proposal calls. The C·I·B's partners and collaborators have made it clear that the research undertaken, the leadership provided in the field, the interactions with the community, and the policy advice provided, can ill afford to be lost.

Abbreviations

ARM	Annual Research Meeting of the Centre for Invasion Biology
BIOME	Biodiversity and Macroecology Group, University of Sheffield
C.A.P.E.	Cape Action for People and the Environment
CASEB	Centre for Advanced Studies in Ecology and Biodiversity
CBD	Convention on Biological Diversity
C·I·B	DST-NRF Centre of Excellence for Invasion Biology
CoE	Centre of Excellence
CSIR	Council for Scientific and Industrial Research
DEAT	Department of Environmental Affairs and Tourism
DMS	Document Management System of the Centre for Invasion Biology
DST	Department of Science and Technology
FET	Further Education and Training
GISP	Global Invasive Species Programme
HERS-SA	Higher Education Resource Services - SA
IAS	Invasive Alien Species
IRSS	Information Retrieval and Submission System of the Centre for Invasion Biology
KPA	Key Performance Area
NEM:BA	National Environmental Management: Biodiversity Act (10 of 2004)
NRF	National Research Foundation
R&D	Research and Development
SAIAB	South African Institute for Aquatic Biodiversity
SANAP	South African National Antarctic Programme
SANBI	South African National Biodiversity Institute
SANParks	South African National Parks
SCAR	Scientific Committee on Antarctic Research
SU	Stellenbosch University
WCED	Western Cape Education Department
WfW	Department of Water Affairs, The Working for Water Programme

1. INTRODUCTION

The Centre for Invasion Biology (C·I·B) is an inter-disciplinary, inter-institutional Centre of Excellence established within the DST-NRF Centres of Excellence Programme. It is co-funded principally by the South African Department of Science and Technology (DST), through the National Research Foundation (NRF), Stellenbosch University (SU), and more recently the South African Department of Water Affairs and Forestry's Working for Water (WfW) programme. The C·I·B was established *de novo* in June 2004 with the vision *'to provide the scientific understanding required to reduce the rate and impacts of biological invasions in a manner that will improve the quality of life of all South Africans'*. In the context of the Key Performance Areas (KPAs) established for all Centres of Excellence, the C·I·B's mission is to:

- undertake research and education in biodiversity and ecosystem functioning, including investigations of the changes in biological diversity that are a consequence of biological invasions, the consequences for ecosystem functioning of these invasions and their remediation, and the longer-term effects of invasions on ecosystem services under a climate of environmental and land-use change;

- remain at the forefront of research regarding biological invasions, biodiversity and ecosystem functioning, by pursuing research excellence and interdisciplinarity, and by encouraging local, regional and international exchanges;

- enhance its national and international standing by means of a coordinated programme of innovative research, the products of which will be broadly disseminated in the international literature; graduates who are sought after for their knowledge, creative, critical thinking, and for their expertise; and a well-supported core and associated staff who are respected and trusted by their peers, clients, and community;

- remain relevant to the needs of the community, focusing on South Africa in the context of trends shaping Africa and the global community.

The mission and strategic direction of the C·I·B was informed and continues to be guided by several major policy documents, including the DST's White Paper on Science and Technology, the National Research Foundation's Strategic Plan, the National Biodiversity Strategy and Action Plan, and the requirements set out in the National Environmental Management Act and two of its subsidiary Acts (Protected Areas and Biodiversity). Nonetheless, because of its primary research function, and the need for that research to inform policy, one of its key roles is also to examine the appropriateness of some of the more specific biodiversity policy recommendations. To this end it maintains close relationships both with those developing policy and those developing regulations that give legal effect to this policy.

Although research, education and service delivery concerning ways to reduce the rates and impacts of biological invasions form the core of the C·I·B's activities (Box 1), these are founded on a broader knowledge base. The rationale for such an approach is straightforward. Biological invasions, and the consequences of human activities more generally, are not ontologically separable from other natural processes, but rather form a clearly identifiable component thereof[1]. In consequence, the development of comprehensive understanding and predictive capability (the two major goals of all science) requires information from a wide variety of fields. Most simply, the impacts of biological invasions on biodiversity cannot be comprehended without a sound understanding of the patterns in and mechanisms structuring biodiversity, and their socio-political context. An example from our own research (Box 9) clearly illustrates how a combination of approaches, from evolutionary physiology to experimental ecology, can help resolve important questions such as the likely effects of interactions between global change drivers on

ecosystem structure. The value of this broad approach was highlighted in 2006 when external science advisors to the C·I·B noted in their letter to the Board, via the Director, that:

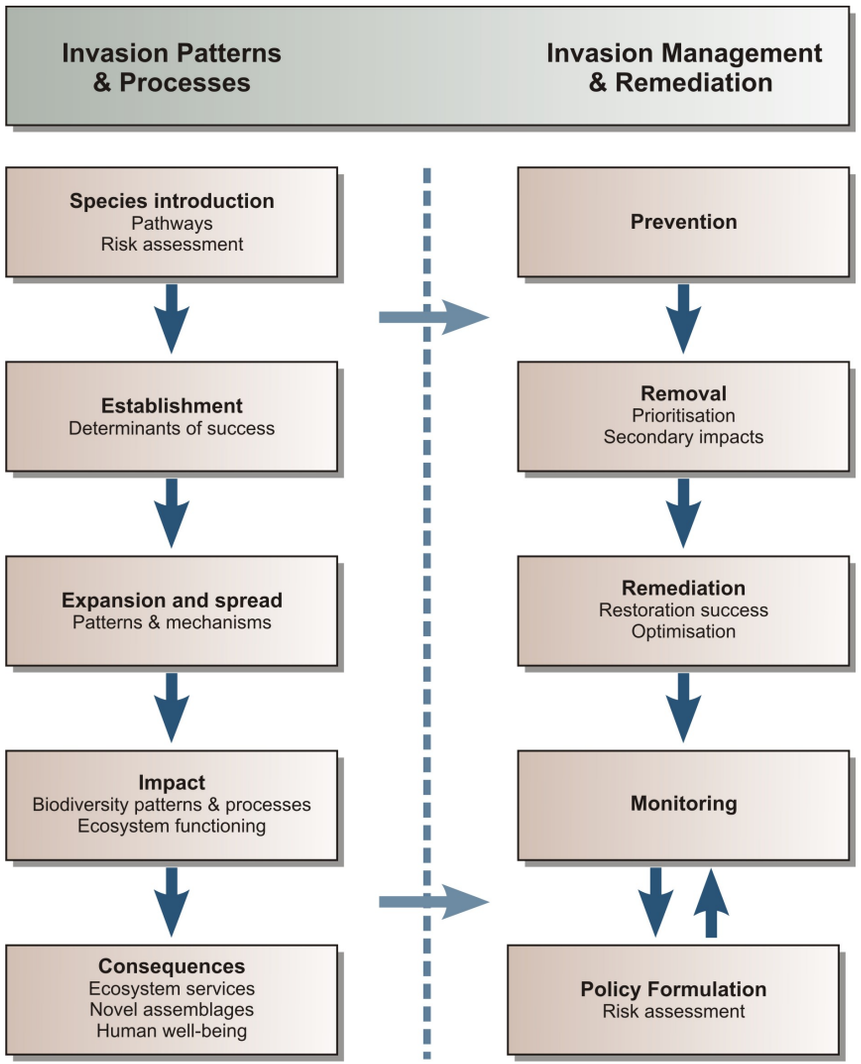
'We see an important feature of the CIB research in the wide range of taxonomic groups studied and variety of approaches used, which is made possible by the balanced composition of the core research team. In most parts of the world, study subjects are still to large extent separated taxonomically, by botanists studying plants, zoologists animals, etc. The close cooperation of researchers with complementary expertise, as practiced at CIB, has the potential to contribute crucially and holistically to our knowledge of the general principles driving biological invasions. This is real ecology. Also, our feeling is that the high-quality research not directly related to invasions, which is also performed at the Centre, creates a broader background of knowledge and expertise from which the studies of invasive organisms profit.'

T.J. Stohlgren, P. Pyšek & T.M. Blackburn

The *'complementary expertise'* referred to in the letter above forms the core component of the C·I·B. It comprises a network of C·I·B researchers, post-doctoral associates, students, and support staff, linked to a broader pool of collaborators via formal and informal agreements. The hub of the C·I·B is located at Stellenbosch University and comprises three academic and 14 (full- or part-time) support staff. The core team members, who all devote only a portion of their research time to the C·I·B, and are not provided with salary support, reside at universities and public entities across the country (Box 2). In addition to the core team, the C·I·B also has short-term relationships with supervisors at other institutions via an 'open bursary programme', a small group of Research Associates, and formal partners with whom we have signed various agreements. Informal collaborations include those typical of all investigator-driven research. Whilst the need to promote collaborative research remains a guiding principle within the C·I·B, it is also acknowledged that the most productive systems are those that have neither too few nor too many connections[2]. In consequence, collaboration is guided and encouraged, but not demanded. It is the outcome of this individual endeavour and collaboration, and their support by the C·I·B's funders, partners and staff, that form the substance of this report. For each KPA, an overview is provided of the rationale for the approach adopted, the inputs that have been required to sustain activity therein, and the outcomes thereof. For the Management KPA, additional information is provided and the format altered to enhance understanding of how the C·I·B hub has approached this crucial aspect of its core business.



Box 1 C·I·B science in a nutshell



2. Research

2.1 Rationale

The C·I·B's research is concerned with the rates and biodiversity impacts of biological invasions, and how these might be reduced and remediated through appropriate policy interventions (Box 1). In consequence, investigations across a wide range of disciplines, taxa, and spatial and temporal scales are supported, with long-term research constituting a central element thereof (Box 3). Several themes characterise the core of the Centre's work (Box 4). These themes have their origins in the work originally proposed in the C·I·B's application to the CoE programme, have been further streamlined through the strategic planning process, and have developed in concert with the field as a whole and the strengths of the C·I·B membership. A spectrum of scientific approaches is encouraged. These range from the investigator-driven to the themed modes; from the theoretical to the empirical; and from the non-instrumental to the instrumental[3]. The overarching goals are to undertake innovative, leading research in biology, and to develop the policy implications and the social dimensions of this work, with biological invasions forming the core around which the research revolves. Excellence in research, and in the quality of human resources, which both characterise the C·I·B and are products of its efforts, form the standard underpinning all other aspects of the Centre's activities.

Box 2 The C·I·B core team

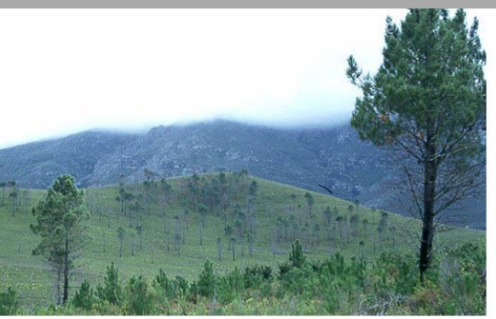
Prof. Steven Chown	*Director and Professor*	*Centre for Invasion Biology and Department of Botany and Zoology, Stellenbosch University*
Prof. Dave Richardson	*Deputy Director: Science Strategy and Professor*	*Centre for Invasion Biology and Department of Botany and Zoology, Stellenbosch University*
Ms. Sarah Davies	*Deputy Director: Operations*	*Centre for Invasion Biology, Stellenbosch University*
Prof. Chris Chimimba	*Professor*	*Department of Zoology and Entomology, University of Pretoria*
Prof. Karen Esler	*Professor*	*Department of Conservation Ecology and Entomology, Stellenbosch University*
Dr. Stefan Foord	*Senior Lecturer*	*Department of Zoology, University of Venda*
Prof. Charles Griffiths	*Professor and Director*	*Marine Biology Research Institute, University of Cape Town*
Dr. Cang Hui	*Researcher*	*Centre for Invasion Biology, Stellenbosch University*
Prof. Steven Johnson	*Professor*	*School of Biological and Conservation Sciences, University of KwaZulu-Natal, Scottsville Campus*
Prof. Melodie McGeoch	*General Manager*	*Cape Research Centre, South African National Parks*
Dr. Augustine Niba	*Senior Lecturer and Coordinator, Pest Management Program*	*Department of Biological Sciences, Walter Sisulu University, Mthatha*
Dr. Heidi Prozesky	*Lecturer*	*Department of Sociology and Social Anthropology, Stellenbosch University*
Dr. Victor Rambau	*Lecturer*	*Department of Botany and Zoology, Stellenbosch University*
Prof. Michael Samways	*Professor and Head*	*Department of Conservation Ecology and Entomology, Stellenbosch University*
Dr. Michael Somers	*Lecturer*	*Centre for Wildlife Management, University of Pretoria*
Dr. Berndt Janse van Rensburg	*Senior Lecturer*	*Department of Zoology and Entomology, University of Pretoria*
Dr. Bettine Jansen van Vuuren	*Senior Researcher*	*Department of Botany and Zoology, Stellenbosch University*
Dr. Brian van Wilgen	*Fellow*	*Natural Resources and the Environment, Council for Scientific and Industrial Research*
Dr. Theresa Wossler	*Senior Lecturer*	*Department of Botany and Zoology, Stellenbosch University*

Box 3 Long-term research: a core component of the C·I·B's work

One of the key benefits of committed funding over the long term is the opportunity it provides for long-term research to be undertaken. Such work is typically not feasible on the basis of short-term (3-4 year) grants. To maximize the benefits of sustained funding, the C·I·B has embarked on several long-term projects. These take two forms. In the first, repeated measurements of sites investigated many years previously are undertaken, providing a second, but often third or fourth data point in a lengthy time-series. This has been the approach to some work on the Prince Edward Islands. For example, a key paper on altitudinal change in invasive and indigenous plant distributions is in press based on work conducted by B.J. Huntley on Marion Island in the 1960s and now repeated by C·I·B members, showing faster expansions by invasive than by indigenous species. Similarly, work showing interactive effects of climate change and predation by introduced house mice is in the process of being further expanded to include sampling in 2008/9, so extending the ecological time series back to 1983 (and including data from 1983, 1986, 1992, 1996, 1999, 2000, and 2008). The full time series goes back 2000 years based on peat cores.

The second approach has been to institute several long-term studies. The major one of these has been several spatial transects investigating ant and beetle diversity in the Western Cape and KwaZulu-Natal. Two of these are altitudinal transects, typically spanning 2000 m. The Cederberg transect has been running since 2003, with five full years of data across 17 sites from the coast at Lambert's Bay to Wupperthal, and including Sneeukop Peak. This area was chosen because it is predicted to change most rapidly with climate change in the Western Cape, is presently free of the Argentine ant (a major invasive associated with human activity), and because it represents one of the few areas where an elevational transect spans both aspects of a mountain range. The baseline science from the transect has already been published, more work is in review, and within the next few years an excellent data set will be available to examine the effects of inter-annual variation on ant assemblages. Within the next 10 years, a key data set on long-term changes will be available. To complement this work, the C·I·B, in partnership with the University of Pretoria, has established a long-term investigation of ant and beetle diversity along Sani Pass in the Drakensberg. The work serves both as a field course for undergraduate students and a long-term data collection opportunity. Matching of the methods with the Cederberg work means that the two transects are comparable, and the Drakensberg sites are also predicted to change substantially with changing climates. The proposed upgrading of the Sani Pass road to a tarred one, and the ongoing progression of *Acacia dealbata* invasions are direct, human-related changes expected in the area.

The altitudinal transect work is supplemented by the limbovane project's large-scale, ongoing spatial transect in the Western Cape (see Box 19). Moreover, an additional elevational study will commence in the Soutpansberg in collaboration with the University of Venda, so adding another transect, this time in a north-south direction. This work is also being supplemented by collaborations with Dr. Catherine L. Parr at the University of Oxford to include data from a range of other biomes in South Africa to provide a full baseline data set on ant diversity across South Africa. These activities all make direct contributions to national commitments to the CBD, as set out in legislation via the National Environmental Management: Biodiversity Act, and the National Environmental Management: Protected Areas Act, and given effect to in the National Biodiversity Strategy and Action Plan.



Box 4 The C·I·B Research Themes

Biodiversity foundations

- Theory
- Behaviour
- Ecology
- Physiology
- Systematics

Large scale patterns in biodiversity

- Abundance, occupancy and abundance structure
- Spatial concordance in diversity and its temporal change
- Listing and mapping of invasive species

Determinants of invasion and scenarios of change

- Determinants of plant invasion
- Propagule pressure and Allee effects
- Biological invasions, economically important species and climate change
- Predictive invasion biology: the Argentine ant
- Marine invasions and temporal change

Interactions between indigenous and invasive species

- The Antarctic as a model system
- Interactions across continental systems
- Honeybee sub-specific dynamics

Impacts of invasion

- Impacts of invasion and remediation
- Risk assessment and scenario planning
- Ecosystem services

Social perceptions and invasions

- Invasive species, community conservation and livelihoods

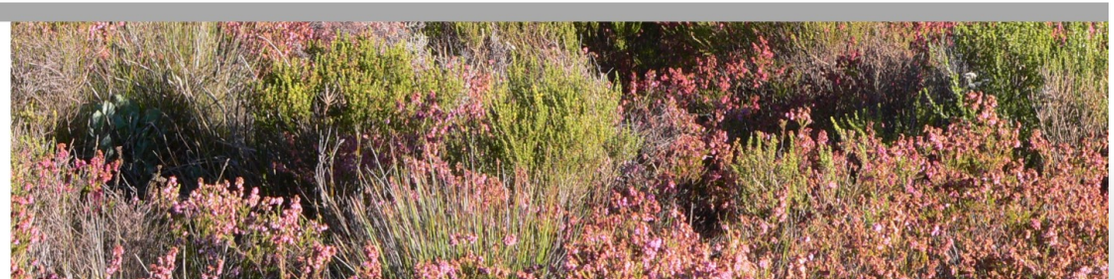
2.2 Inputs

To ensure high quality, sustained research output, several key inputs are required. Among them, critical, innovative and reasonably well-supported researchers at the senior, post-doctoral and post-graduate levels are clearly the most significant. If all science is based on '*conjecture and refutation*'[4] then those with a talent both for imaginative and for critical thinking are of most value, irrespective of the approach they adopt, so long as the knowledge they produce meets the requirements of reliability[5]. Although innate capacity for such thinking is clearly important, an environment that promotes, facilitates and provides opportunities for it is of considerable significance too. Excellent researchers need to be encouraged to create and make use of opportunities for developing their talents. In South Africa, the creation of these opportunities needs to take cognisance of the inequities of the past. For these reasons, the C·I·B core team comprises established and new researchers from a variety of institutions and backgrounds, connected by the Centre's common research themes and an active process of research facilitation and networking via meetings, symposia, workshops, and electronic media. Although much debate swirls around the ways in which research profile and excellence might be measured, internationally Hirsch's *h*-index[6] provides one way of doing so, whilst the NRF's rating system provides another perspective. By both measures, and by gender and age profile, the C·I·B has an excellent blend of established and developing researchers (Boxes 2 and 5). Moreover, post-doctoral and student support from the C·I·B is outstanding, comparable with and often outpacing funding from other sectors in the National System of Innovation (though by no means the highest). Likewise, researchers and their groups have access to excellent infrastructure and support via the collaborative nature of the C·I·B network.

2.3 Outputs

Between June 2004 and June 2008, the C·I·B published a total of 246 primary research and review papers and commentaries across all of its major research themes (Appendix 1). These works appeared in a full range of high impact interdisciplinary and disciplinary outlets, such as *Nature* (1), *Science* (2), *PLoS Biology* (1), *PNAS* (1), *Trends Ecol. Evol.* (2), *Annu. Rev. Ecol. Evol. Syst.* (1), *Ecol. Lett.* (1), *Biol. Rev.* (1), *Am. Nat.* (4), *Ecology* (1), and *Proc. R. Soc. B* (6). Reviewing and contextualizing this work would require several synthesis papers covering a variety of topics (Box 4). In consequence, rather than so doing, ten key papers have been selected which either have had major impacts on the field or on policy, or seem likely to do so. These papers reflect a broad range of the C·I·B's research themes, and the activities of its researchers and students (Boxes 6 to 15). A full, searchable list of the C·I·B's research outputs is also available at http://www.sun.ac.za/cib/2008Review/.

Scientific outputs in edited books have also formed a significant component of the Centre's research (Box 5), and the Centre has also led the production of a key, edited book on the research undertaken at the Prince Edward Islands over the last 50 years. *The Prince Edward Islands. Land-sea Interactions in a Changing Ecosystem* (Eds. S.L. Chown and P.W. Froneman) is considered the seminal, modern work on the islands (see forthcoming review in *Polar Record*). This reflects the Centre's ongoing commitment to the development of high quality research in the Antarctic Region in keeping with the R&D Strategy set out by the DST, and the focus on the region that forms part of its ten year plan (2008-2018) (see http://www.dst.gov.za/publications-policies).



Box 5 Research indicators

19	Core team members	2	A-rated
		3	B-rated
		5	C-rated
		3	Y-rated
20	Post-doctoral associates	2	ISI h-index 30 or higher
		2	ISI h-index 20 to 29
		6	ISI h-index 10 to 19
4	Years since initiation	246	Primary research outputs
		4	ISI-accredited outputs with IF ≥ 15
		49	ISI-accredited outputs with 3.5 ≤ IF < 15
		15	Book chapters
		3	Books

According to the definition of gender relevance provided by the '*NRF Framework for Centres of Excellence in the South African National System of Research and Innovation*' document (dated May 2003), much of the research undertaken by the C·I·B is gender neutral. The research and its outcomes have little differential relevance to men or women and are unlikely to affect relationships between the genders.

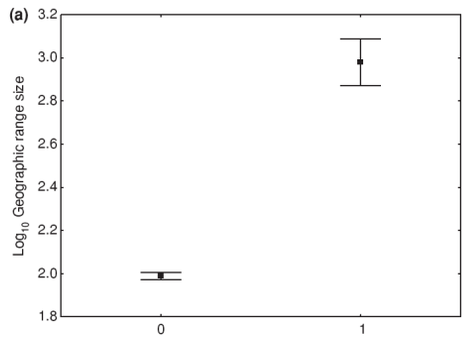
Nonetheless, some of the work produced to date does have considerable gender relevance. For example, the brunt of landscape-level impacts of invasive alien species is often borne by women, who are responsible for subsistence farming activities and household provisioning in rural areas. They are also major contributors to the Working for Water Programme's activities on the ground. Therefore, C·I·B research into reducing the rates of invasion and improving remediation has direct gender relevance in these contexts.

C·I·B core team members have also been responsible for promoting the role of women in science through formal participation in such activities. For example, K.J. Esler plays a significant role in South African Women in Science and Engineering, and through that route C·I·B members have contributed to promoting science as a career path for women. The overall C·I·B strategy also includes encouragement of women into and in science and strives to ensure that they remain in the science system. Considerable success has been had in this regard, from Centre staffing (of the 17 hub staff, 10 are women) through to student graduations (see below), to the ongoing uptake of C·I·B women graduates by the market place (Box 17). Moreover, wherever possible, career development opportunities for women within the C·I·B are supported, often with assistance from Stellenbosch University (e.g. the participation of S.J. Davies in the HERS-SA Academy in 2007). In this way the activities of the C·I·B have a profound, differential relevance to women.

Box 6 Understanding spatial patterns in biodiversity – new ways based on matrices

Gaston, K.J., Chown, S.L. & Evans, K.J. (2008) Ecogeographical rules: elements of a synthesis. *Journal of Biogeography* **35**, 483-500. http://www3.interscience.wiley.com/journal/119402428/abstract doi:10.1111/j.1365-2699.2007.01772.x

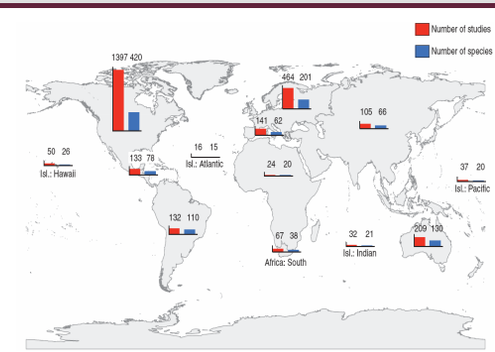
The development of a synthetic approach to understanding spatial patterns in biodiversity, particularly of the way in which these patterns interact, constitutes a significant challenge for ecology and biogeography. Although it has been recognized that these patterns and the mechanisms underlying them play out at the intraspecific, interspecific and assemblage levels, how these levels and their mechanisms are linked and might constrain patterns is not clear. In this study, the unifying role that geographic ranges play in linking these patterns is set out. In particular, it is shown that an r x c matrix approach can form the basis for understanding all ecogeographic patterns and the mechanisms underlying them. Not only does it provide a way of linking patterns at all levels, but it forms the basis for null model approaches used to understand ecological patterns and their dynamics. In consequence, a disparate set of patterns and likely mechanisms are tied together immediately and formally, thus enabling further exploration of interactions that have always been a challenge for the field. Models to do so are sorely lacking and this work has stimulated further development thereof. This study has also demonstrated that at several of the levels, generalities concerning patterns are not perhaps as easily made as has been thought to be the case. For example, small range species seldom form the basis for investigations of geographic variation in traits, even though such species are most common in assemblages (see figure, showing smaller ranges for species not the subject of ecogeographic studies than for those which have been investigated).



Box 7 Invasion ecology: are we studying enough organisms in enough places?

Pyšek, P., Richardson, D.M., Pergl, J., Jarošík, V., Sixtová, Z. & Weber, E. (2008) Geographical and taxonomical biases in invasion ecology. *Trends in Ecology and Evolution* **23**, 237-244. http://www.sciencedirect.com/science/journal/01695347 doi:10.1016/j.tree.2008.02.002

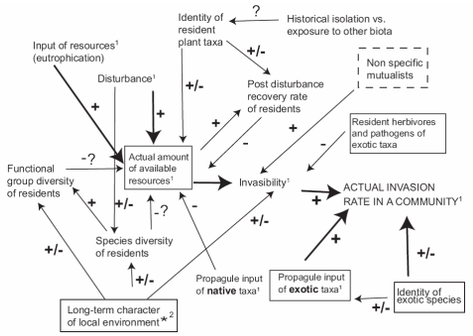
Much progress has been made in developing theories of and principles in invasion ecology. The field is striving for a synthesis, with generalizations that apply widely across taxonomic groups and geographical regions. This study explored biases in the study of invasions by examining which organisms are best studied and where detailed organism-focussed studies have been conducted. Almost half (48%) of all detailed studies of invasive alien organisms since 1980 focussed on plants; invertebrates and vertebrates accounted for 36% and 14% of studies, respectively. This pattern roughly mirrors the general level of management attention given to the different groups worldwide. Mammals and crustaceans are overrepresented in published studies, whereas birds, bryophytes, insects, and plants are underrepresented. Africa and Asia are markedly unrepresented among the world's regions when one tallies detailed studies of invasions, although invasions have received reasonable attention in South Africa (much of it from C·I·B core team members). Bars on the figure indicate the proportional contribution of world regions to the total number of invasive species studied (n = 892) and to the total number of studies (n = 2670). South Africa is a significant global player in the study of biological invasions. One of many challenges is to facilitate research in other parts of Africa.



Box 8 Taking stock of the invasion ecologist's toolbox

Rejmánek, M., Richardson, D.M., Higgins, S.I., Pitcairn, M.J. & Grotkopp, E. (2005) Ecology of invasive plants – state of the art. In: Mooney, H.A., Mack, R.N., Mc Neely, J.A., Neville, L., Schei, P.J. & Waage, J. (eds), *Invasive alien species: A new synthesis,* pp. 104-161. Island Press, Washington, D.C. ISBN-13: 978-1559633635

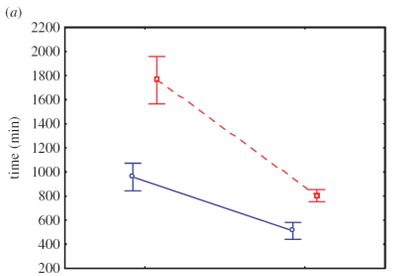
Five questions form the backbone of invasion ecology: Which taxa invade? How fast? What makes ecosystems invasible? What is the impact? How can we control or eradicate harmful invaders? There has been an explosion of research in this field. This book chapter, drawing heavily on South African examples, provides the most comprehensive review to date of progress towards answering the above questions for plant invasions. The authors argue that good predictive capacity can be distilled from findings of several discrete threads of research. For example, useful probabilistic predictions about invasion potential can be made from metrics of initial population size, residence time, and the number of introduction events. Empirical taxon-specific approaches, drawing on previously documented invasions of particular taxa, add considerable power to such predictions. Careful comparisons of traits of invasive and non-invasive taxa have yielded both general and habitat-specific screening procedures. Manipulative experiments that tease apart intrinsic and extrinsic factors underlying invasion success of particular taxa and invasibility of particular habitats have sharpened predictions. The figure summarizes causal relationships between factors and processes that drive plant invasions. The thickness of arrows indicates relative importance of positive (+) and negative (-) relationships. This framework has focussed the invasion ecology research agenda at the C·I·B.



Box 9 Global change-type drought promotes invasion via phenotypic plasticity

Chown, S.L., Slabber, S., McGeoch, M.A., Janion, C. & Leinaas, H.P. (2007) Phenotypic plasticity mediates climate change responses among invasive and indigenous arthropods. *Proceedings of the Royal Society of London* B **274**, 2531-2537. http://journals.royalsociety.org/content/b721k74155j735q7 doi:10.1098/rspb.2007.0772

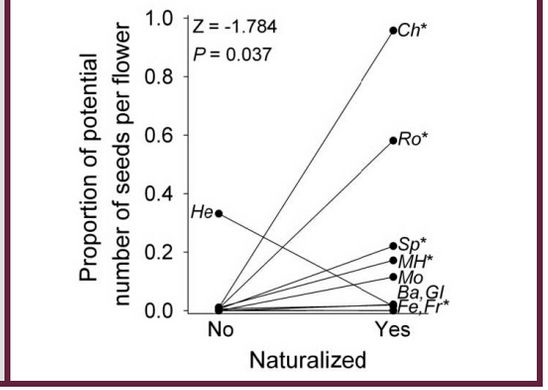
Synergies between global change and biological invasion have been identified as major potential threats to global biodiversity and human welfare. The global change-type drought characteristic of many temperate terrestrial ecosystems is especially significant because it will apparently favour invasive over indigenous species, adding to the burden of conservation and compromising ecosystem service delivery. However, the nature of, and mechanisms underlying, this synergy are virtually unexplored in terrestrial systems. In this study, the mechanisms underlying such responses were explored in springtails in a temperate system. The investigation showed that invasive and indigenous springtail species differ in the form of their phenotypic plasticity such that warmer conditions promote survival of desiccation in the invasive species and reduce it in the indigenous ones (figure, desiccation resistance of an invasive species showing longer survival following high temperature exposure (red)). This physiological outcome is reflected in the responses of the species to a manipulative field experiment where, following drying and warming, densities of the indigenous species declined, but those of the invasive species did not. Thus, the predicted synergy between invasion and global change type-drought is supported. This work is one of very few empirical studies exploring climate change effects on biological invasions, and thus the potential synergy of these environmental change drivers. It has attracted substantial attention in the scientific literature, and also did so on publication in the popular media.



Box 10 Baker's law and the likelihood of invasion

van Kleunen, M., Manning, J.C., Pasqualetto, V. & Johnson, S.D. (2008) Phylogenetically independent associations between autonomous self-fertilization and plant invasiveness. *American Naturalist* **171**, 195-201. http://www.journals.uchicago.edu/doi/abs/10.1086/525057 doi: 10.1086/525057

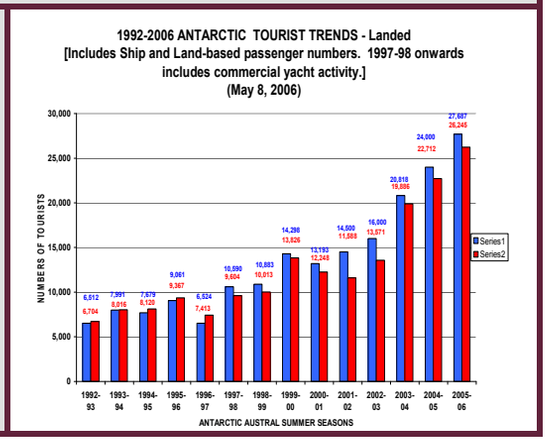
Baker's law states that any organism capable of unisexual or uniparental reproduction will benefit through reproductive assurance in the absence of pollinators and suitable mates following long-distance dispersal. This law may help to explain variation in success of naturalised and invasive species, since the ability to reproduce autonomously may increase propagule pressure and hence the probability of successful establishment in a new environment. In this study, this hypothesis was tested in an explicit, phylogenetic framework by comparing fruit and seed production among ten pairs of congeneric South African Iridaceae species used in the international horticultural trade. Each pair of species comprised a naturalized (i.e. potentially or actually invasive) and a non-naturalized species (non-invasive). The pairs spanned nine genera with ability to naturalise or invade, thereby controlling for phylogenetic associations. Sixteen of the 20 species produced fruit in the absence of pollinators. Fruit set and the number of seeds per flower was higher in naturalized species in eight of the ten species pairs (as shown in the figure). The four species that contributed most to the positive association between autonomous reproduction and successful naturalization are already listed as invasive weeds. Breeding system may thus be an important predictor of naturalisation and invasion success and should be included in screening protocols for assessing potentially invasive plants (and other organisms).



Box 11 Aliens in Antarctica: implications and policy

Frenot, Y., Chown, S.L., Whinam, J., Selkirk, P.M., Convey, P., Skotnicki, M. & Bergstrom, D.M. (2005) Biological invasions in the Antarctic: extent, impacts and implications. *Biological Reviews* **80**, 45-72. http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=275546 doi: 10.1017/S1464793104006542

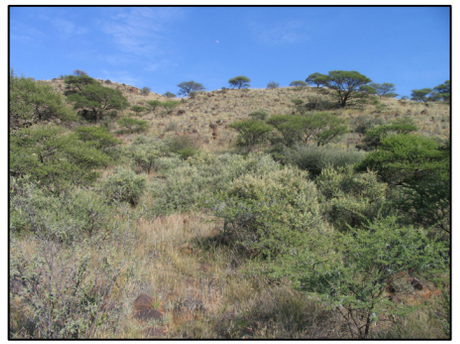
Despite being among the most pristine environments on Earth, Antarctica and its surrounding islands are not free from biological invasions. These have led to substantial impacts at the species and ecosystem levels on many islands, resulting in local extirpations, changes in nutrient cycling and indirect interactions. Mesopredator and herbivore release following eradication, with unanticipated and substantial impacts, have also been recorded in the area. Although invasion is less extensive on the Antarctic continent, rapid warming in the Peninsula and Scotia Arc area coupled with an ongoing increase in visitor (scientific and tourist – see the figure for tourists to Antarctica, © IAATO, http://www.iaato.org/) numbers seem set to change this situation. The research presented in this paper and a talk by one of the authors, S.L. Chown, to the XXVIII Antarctic Treaty Meeting, galvanized the Antarctic Treaty Parties to set in motion a wide variety of policy interventions to reduce the rate and impacts of invasions to the area. Biological invasions and management interventions to reduce them are now a standing agenda item for the Committee for Environmental Protection of the Antarctic Treaty System. This international, inter-governmental committee is charged with the environmental stewardship of Antarctica, and has taken much of its cue for Invasive Alien Species interventions from this paper, and from the subsequent workshops and discussions generated by it. The work has not only garnered considerable scientific interest, but has resulted in major international policy development.



Box 12 Invasion by infiltration – plant invasions in semi-arid savannas

Milton, S.J., Wilson, J.R.U., Richardson, D.M., Seymour, C.L., Dean, W.R.J., Iponga, D.M. & Procheş, Ş. (2007) Invasive alien plants infiltrate bird-mediated shrub nucleation processes in arid savanna. *Journal of Ecology* **95**, 648-661. http://www3.interscience.wiley.com/journal/118509735/abstract doi: 10.1111/j.1365-2745.2007.01247.x

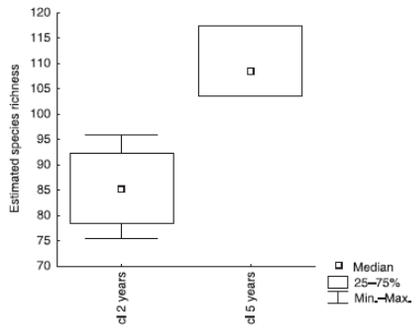
Symbiotic relationships between plants and other organisms are crucial mediators of invasion success for introduced plants. Seed dispersal and pollination by animal agents and relationships between plants and micro-organisms in the soil often determine whether a species will invade, and the extent to which it will spread in new environments. Biological invasions also have a profound effect on naturally-occurring mutualisms in many ecosystems. Some such impacts are widely known, but the mechanisms that produce them are poorly understood. A novel, natural experiment, provided by the planting of a large number of alien fleshy-fruited woody plants in close proximity to a natural semi-arid savanna ecosystem near Kimberley (see figure) over several decades, enabled researchers to explore the mechanisms that facilitated invasion of this ecosystem by several alien species. They could explain invasion patterns by describing how the alien species infiltrated naturally-occurring seed-dispersal networks, and the complex interplay between propagule pressure, facilitation (including the use of native tree as nurse plants), and a range of other factors. The invasions are at an early stage, but are destined to transform the invaded ecosystems. These findings add to the growing body of evidence showing that the mutualisms are both key drivers of invasions and key casualties of invasions. The results also have important implications outside the field of invasion ecology for understanding the importance of mutualistic interactions in population dynamics.



Box 13 Management interventions for triffid weed – the sooner the better

Mgobozi, M.P., Somers, M.J. & Dippenaar-Schoeman, A.S. (2008) Spider responses to alien plant invasion: the effect of short- and long-term *Chromolaena odorata* invasion and management. *Journal of Applied Ecology* **45**, 1189–1197. http://www3.interscience.wiley.com/journal/120696199/abstract doi: 10.1111/j.1365-2664.2008.01486.x

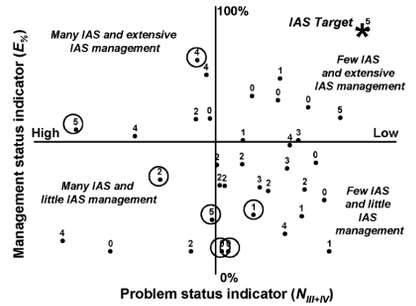
Chromalaena odorata is one of the most significant invasive alien species in savanna riparian zones of southern and central Africa. This investigation of arachnid species richness, diversity, abundance and community structure in areas of the Hluhluwe-iMfolozi Park, KwaZulu-Natal, that have been invaded by *C. odorata* for different periods, or cleared, has revealed the importance of early clearing. All of the invaded sites had lower spider diversity and species richness than did the uninvaded control site. Sites that had been invaded for ten or 20 years had lower spider species diversity and richness values than did those that had been more recently invaded. However, sites that had been cleared of *C. odorata* showed considerable recovery towards the pre-invasion state, especially the older cleared sites (see figure). The study highlights the continuing decline in spider diversity and richness over long periods of invasion and hence the importance of clearing as early as possible. It also emphasizes the significance of clearing for the restoration of biodiversity, so demonstrating the net biodiversity returns of clearing programmes such as those underwritten by WfW. Not only is the WfW providing excellent social investment, but it is also contributing substantially to biodiversity restoration, as demonstrated both by this study and by others in the Fynbos biome that have shown substantial recovery of aquatic and riparian species following clearing.



Box 14 Biological invasion and the CBD's 2010 Targets

McGeoch, M.A., Chown, S.L. & Kalwij, J.M. (2006) A global indicator for biological invasion. *Conservation Biology* **20**, 1635-1646. http://www3.interscience.wiley.com/journal/120829735/abstract doi: 10.1111/j.1523-1739.2006.00579.x

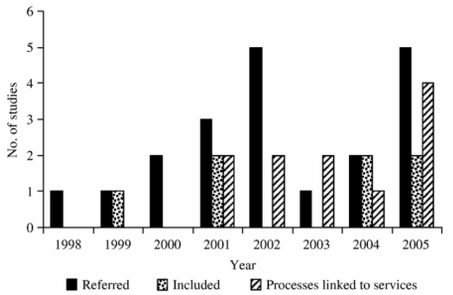
"Trends in invasive alien species" is one of only two indicators of threat to biodiversity that form part of the Convention on Biological Diversity's (CBD) framework for monitoring progress toward its commitment to achieve by 2010 a significant reduction in the current rate of biodiversity loss. To date, however, there is no fully developed indicator for invasive alien species (IAS) that combines trends, derived from a standard set of methods, across species groups, ecosystems, and regions. This study provides a rationale for the form and characteristics of an indicator of trends in IAS that will meet the 2010 framework goal and targets for this indicator. Single and composite indicators are developed that include problem-status and management-status measures that are designed to be flexible, readily disaggregated, and as far as possible draw on existing data. The single indicators at national and global scales are numbers of IAS and numbers of operational management plans for IAS. Global trends in IAS are measured as the progress of nations toward the targets of stabilizing IAS numbers and the implementation of IAS management plans (see figure). The proposed global indicator thus represents a minimum information set that most directly addresses the indicator objective and simultaneously aims to maximize national participation. Currently, components of this indicator are being developed by the C·I·B, for the CBD in association with a range of partners via a collaboration with the Global Invasive Species Programme.



Box 15 Adding ecosystem services to the criteria for conservation planning

Egoh, B., Rouget, M., Reyers, B., Knight, A.T., Cowling, R.M., van Jaarsveld, A.S. & Welz, A. (2007). Integrating ecosystem services into conservation assessments: A review. *Ecological Economics* **63**, 714–721. http://www.sciencedirect.com.ez.sun.ac.za/science/journal/09218009 doi:10.1016/j.ecolecon.2007.04.007

Ecosystem services are the benefits that humans derive from natural environments. Traditional conservation has focussed on areas with high concentrations of species, particularly endemic species, and where there is a high risk of habitat loss. Increasing pressure on land for utilitarian purposes means that more attention is being given to the rationale behind prioritizing conservation based on the value of ecosystem services. South Africa is a global leader in this field. This focus is driven by the need to modify policies. Rapid population growth and changing environmental and socio-political conditions demand new paradigms to ensure sustainable development while conserving the region's natural capital. Our ecosystems provide sound opportunities for cutting-edge research in this field. The country has a heterogeneous landscape, rich biodiversity, and long history of conservation planning and research on the extent to which various features of biodiversity serve as surrogates for overall biodiversity. Also, the country has excellent research foundations in agriculture and hydrology, and good spatially-explicit data on biophysical features. This study addresses the need to develop an integrated approach for merging different conservation objectives to allow for human well-being to be explicitly considered in conservation planning. A review was done of conservation assessments worldwide. Only 7% of assessments explicitly included ecosystem services, while another 13% referred to ecosystem services implicitly as a rationale for conservation. Most assessments used data on biodiversity patterns; fewer than 20% used data on ecological processes. The figure shows that the number of assessments that refer to ecosystem services (even if they do not address them in detail) is increasing over time. The study highlights the urgent need for much improved understanding of spatially-explicit links between different categories of ecosystem services and features of biodiversity. It also underscores the importance of adapting currently available planning tools to accommodate mapped ecosystem services.



3. Education and training

3.1 Rationale

The education and training of skilled human resources for the South African National System of Innovation forms a central component of the business of the C·I·B. Indeed, the large majority of the research undertaken by the Centre takes place via student training at the post-graduate level. However, the C·I·B's contributions neither begin nor end at this level. Rather, taking cognisance of the challenges facing secondary and higher education in South Africa, the Centre's contributions commence at the Grade 10 level when opportunities still exist to select subjects appropriate for a science career. Through the Iimbovane outreach project the C·I·B engages directly with the Western Cape Education Department, its curriculum advisors, and a large group of teachers and learners. The idea is to assist with the implementation of the National Curriculum Outcomes, and specifically with Learning Outcome (LO) 1: '*Scientific inquiry and problem solving skills*', LO 2: '*Construction and application of life science knowledge*' and LO 3: '*Life sciences, technology, environment and society*' in a way that also gives learners direct access to the practise of science and young scientists. Learners not only benefit substantially from the experience in their formal activities, but C·I·B staff and volunteers are able to inform learners about what is required to become a scientist, show them how much satisfaction can be gained from such a career, and dispel any inaccurate perceptions of what is required to make a career of science. Irrespective, one of the major reasons for the intervention is also to develop a positive perception of science among young South Africans. In a world plagued increasingly by a failure of reason, an appreciation for the value of constructive debate and reliable knowledge needs to be more widely developed[6].

Recognising the urgent requirement for improving the demographic, gender and age profiles of the South African scientific community, and for retaining excellence in the science system, the C·I·B supports a group of 3rd and 4th year students who meet either (and increasingly both) of these requirements. The main idea is to draw students into the Centre's sphere of influence and to encourage them to think about the research done by the Centre as a rewarding (in all senses) career path. In consequence, as long as the projects (usually quite small at 3rd year level) are in the biodiversity field and the students have a real interest, funding is made available to them. At higher post-graduate levels, a focus on Centre work becomes more significant a demand placed on each student. Further to encourage students from the disadvantaged groups, in collaboration with the DST-NRF CoE in Birds as Keys to Biodiversity, the C·I·B has held two Biodiversity Conservation Academies (in 2006 and 2008) and intends to hold these on an annual basis in future. Intensive field work and discussions about biodiversity conservation are held. The Academy is open to 2nd, 3rd and 4th year students from across the country.

Once students have entered the post-graduate stream within the C·I·B, the main goals are to ensure that they undertake excellent work and emerge as graduates who are sought after either by supervisors further along the degree pipeline or by employers. Indeed, an important aim is to ensure that our graduates do not simply leave the science system, but are accommodated in appropriate positions within which they can develop their early careers.

3.2 Inputs

Among the most significant of the inputs made to this KPA are excellent financial support at all levels and supervisors who are not only intellectual leaders, but who also provide an encouraging environment with mentorship where it is required. Co-supervision across fields forms an important component to maximize academic leadership and interdisciplinarity. Students are further encouraged to excel through the award annually of one to three travel prizes of R 20 000 each to the best student presentations/posters at the Annual Research Meeting (ARM). These awards usually are spent on research travel to international collaborators or

conferences. At the schools level, the Iimbovane outreach project has substantial international funding and a staff of two core personnel and several volunteers. In addition to these inputs, C·I·B core team members (and especially senior hub personnel) retain close working relationships with major employers throughout the country, including the South African National Biodiversity Institute (SANBI), SA National Parks (SANParks), CapeNature, WfW, CSIR, DST, NRF, Department of Environmental Affairs and Tourism (DEAT), several consulting agencies, and a variety of tertiary institutions. These relationships are instrumental in helping graduates and exiting post-doctoral associates to develop successful careers. On the upstream side of the student pipeline, the C·I·B Director and core staff also regularly visit institutions to make students and researchers aware of a range of possibilities for collaboration with the Centre. To this end, an open bursary programme has also been established to encourage students from the designated groups to work with the Centre. The open programme enables students from any tertiary institution, who are keen to work in the C·I·B's broader field, to remain working with their supervisor at their institution of choice, while joining the broader C·I·B community. On an annual basis, applications for student and post-doctoral support are scrutinized by the Director and Deputy Directors for novelty, fit to C·I·B strategy, the overall balance of work across disciplines, taxa and team members, and the position of C·I·B overall relative to the requirements of its Service Level Agreement. On these grounds, decisions are made and applicants are informed of the outcome. Discussion is welcomed in cases of dispute, but the central decision nonetheless remains final. Whenever funding is available, additional calls are announced and to encourage applications more generally, an 'open call' stands throughout the year for special cases.

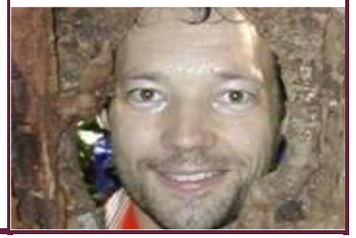
3.3 Outputs

It is important to recognize that the C·I·B was formed *de novo* in June 2004. Although a few students from the members' research groups were drawn into the C·I·B immediately, most student registrations commenced in 2005. In consequence, only 3.5 full years of student training have been at the Centre's disposal. Nonetheless, over this period, the C·I·B has supported (the students register at a variety of institutions) 98 students and 16 post-doctoral associates (228 annual registrations in total), of which 57 students have graduated (Box 16). These graduates, and post-doctoral associates who have now left the C·I·B, are employed at a wide range of organizations both domestically and abroad (Box 17). The C·I·B has been especially successful at addressing the gender bias in science, with 36 of its 57 graduates being women. Notably, the first four Masters graduates are women, and all achieved their degrees with distinction. The C·I·B's first, fully-funded Ph.D. graduate is also a woman.

Box 16 Education and training indicators

228	Student and post-doc registrations supported	38	Students p.a. on average
		7	Post-doctoral associates p.a. on average
		90	Black students and post-doc registrations
		129	Women students and post-doc registrations
57	Graduations	2	Doctoral
		13	Masters
		24	Honours/final year of four-year degree
		18	Undergraduate
		13	Graduates who continued to other degrees within the Centre
		2.2 yr	Average duration of completed masters degrees
		3.3 yr	Average duration of completed doctoral degrees

Box 17 Market take-up of C·I·B graduates and post-doctoral associates

Ms. Lihle Dumalisile (M.Sc., 2007), Principal Nature Conservation Scientist (Mammals), Gauteng Department of Agriculture, Conservation & Environment		Ms. Shelley Vosse (M.Sc., 2007), Agricultural Analyst, Genesis Analytic Climate Change Practice, Cape Town	
Ms. Jeanne Gouws (M.Sc., 2007), Conservation scientist, Junior Manager of the River Conservation Unit, Scientific Services, CapeNature		Dr. Elrike Marais (Ph.D., 2008), Post-doctoral researcher in collaboration with the Global Invasive Species Programme	
Ms. Mandisa Mgobozi (M.Sc., 2007), Ecologist, Ezemvelo KZN Wildlife, Hluhluwe Research Centre, Hluhluwe-iMfolozi Park		Dr. Şerban Procheş (Post-doctoral associate, 2005-6), Senior Lecturer, School of Environmental Sciences, University of KwaZulu-Natal, Durban	
Ms. Ndivhuwo Luruli, neé Netshilaphala (M.Sc., 2007), Professional Officer, Institutional Development Programme, National Research Foundation		Dr. Mark van Kleunen (Post-doctoral Associate 2006-7), Lecturer, Institute of Plant Sciences, University of Bern, Altenbergrain 21, CH-3013 Bern, Switzerland	

Excellent progress has also been made in addressing the need for equity and redress in South Africa. Of the students who have received support, 45 are South Africans from the designated groups and seven are Africans from outside our borders, in keeping with the nation's pledge to contribute substantially to the New Partnership for Africa's Development. Of those that have already graduated, the majority have gone on to careers in conservation, science or science management in South Africa. A particularly noteworthy recent achievement was the award of the C·I·B's top student prizes in 2007 exclusively to students from the designated groups. The external science advisors to the C·I·B Board, together with Prof. Andrew Clarke from the British Antarctic Survey, agreed that Natasha Mothapo and Lukeshni Chetty made the best student presentations at the C·I·B's ARM. In so doing they confirmed that much, previously unrecognized, talent remains to be drawn into the South African science system, and that the C·I·B is succeeding in doing so. The successes in this regard were also highlighted in a letter to the C·I·B and a range of other role players in the South African ecological arena, by Dr. Guy Preston, Programme Leader of WfW, who, after attending the ARM in 2007, specifically drew attention to the fact that:

'*The CIB is doing vital work in preparing the next generation of invasive specialists, and addressing transformation imperatives in doing so.*'

As part of its collaboration with WfW, the C·I·B is also developing a set of short courses for managers from WfW, and has also involved managers from SANParks and from CapeNature. These courses are intended not only to provide information to managers about new scientific developments relevant to the work they do, but also to enable the C·I·B to gain an understanding of challenges faced by managers that require concerted research effort for their solution. Such research effort might cover any approach from the purely technical to that of policy development.

4. Information brokerage

4.1 Rationale

In many ways, the central role of the C·I·B can be seen as fostering a knowledge economy, and using the outcomes of its knowledge production to promote a sustainable society to the benefit of all life. In consequence, information brokerage across a wide variety of levels is valued as a core component of the C·I·B's business. From the outset the approach has been taken that only two ways exist for the knowledge, skills and insights of the C·I·B team to be made widely available. First, direct interactions with the C·I·B core team, staff, post-doctoral associates and students provide a means for a relatively small number of people, though across a broad spectrum of society, to benefit from the C·I·B's knowledge generation. Typically this contact takes place via scientific and public lectures; researchers interfacing with students and the general public; interactions at workshops, public meetings and science expos; through the direct media such as radio talk shows; and, importantly, through the limbovane outreach project to educators at the secondary school level and their learners (Grade 10 and extending to Grade 11). Second, indirect interactions take place via the dissemination of knowledge through the primary scientific literature, scientific books, popular articles and books, the printed and radio and television media, and through web resources. Since its inception, the C·I·B has made use of the full range of information brokerage vehicles at its disposal, recognizing that as an essential element of the South African, African and global knowledge economies, it must serve society at a broad range of levels. Acknowledging especially that public perceptions concerning non-indigenous species vary considerably, from outright opposition to considerable support for their ongoing introduction and utilization, the C·I·B also seeks to ensure that it is considered a reliable source of impartial information especially where risk assessment and policy formulation are concerned. In this regard, the role of independent researchers at tertiary institutions is especially significant, although in a

modern, user-funded society, this independence is increasingly difficult to sustain and to identify[3].

In addition to external knowledge brokerage, the C·I·B considers it essential to invest substantially in ensuring the long-term security of its knowledge generated, including not only research data and products, but also the documentation that underpins the running of the Centre.

4.2 Inputs

Despite the growth in the numbers of journals over the past two decades, the publication of primary research papers in high quality outlets remains a substantial challenge for many researchers. Clearly, excellent scientific research is the first step towards excellent publication. However, thereafter, a certain craft is required to have the work published in outlets where it will achieve maximum visibility. To assist core team members, post-doctoral associates, and a small group of external delegates, in this regard, the C·I·B held a publishing workshop in September 2006 involving two editors-in-chief of international scientific journals, and a senior publishing editor from (at the time) Blackwell. In addition, senior core team members are encouraged to provide assistance to early career researchers where this is requested. All C·I·B members are also expected to publish their work and to present it at meetings of their peers (though taking cognisance of the climate change impacts of air travel), and excellent funding levels help to make this possible. The Outreach Manager solicits information from core team members that can be used for media releases, 'nuggets' to the NRF and for the C·I·B home page, and as the basis of interviews with the press, radio or television media. The Outreach Manager is also responsible for developing and maintaining interactions with key personnel in the media, and the Director assists by making information on his expertise available to several media representatives. A close interaction with the Stellenbosch University Faculty of Science Press Officer is an especially important and fruitful component of this strategy.

Two C·I·B hub staff have also attended courses on popular writing for the media. In keeping with its goals to promote an understanding of the risks posed by invasive alien species, but bearing in mind the value of many non-indigenous ones to society, the C·I·B has also invested in a popular book on invasions. The book, authored by Leonie Joubert, who wrote the popular climate change book '*Scorched*', is currently under consideration by Wits University Press. Both Leonie and Dave Pepler, presenter of the popular television programme 'Groen' (= Green), are associates of the C·I·B who regularly interact with the public through the newspapers, popular magazines and television. As the major outreach activity of the C·I·B, the limbovane outreach project has substantial staff and financial support from the Centre's core budget. It is also supported by a U.K. Darwin Initiative Grant led by Prof. Kevin J. Gaston (University of Sheffield), constituting financial, human resources and intellectual assistance.

In addition to these inputs, the C·I·B has received considerable assistance from Stellenbosch University, at no cost, for the development of two key systems for archiving and retrieving information. The C·I·B's Information Retrieval and Submission System (IRSS - https://ir.sun.ac.za/cib/) was customized for the Centre's use from the DSPACE environment by SU Library Service with assistance from SU Information Technology. This system forms the backbone of the C·I·B data archiving and retrieval process. In addition, SU IT services has made available its Document Management System (DMS) for use by C·I·B members for internal management of key working documents, information, and small collaborative research projects. Both electronic resources are invaluable parts of the information brokerage strategy of the C·I·B.

4.3 Outputs

Considerable success has been achieved at indirect information brokerage. Over its four-year lifespan, the C·I·B has published a wide range of research papers, book chapters, and scientific books (Box 5). It has also excelled at producing popular

articles and books, and in raising important issues in the media or simply increasing the public profile and appreciation of the importance of invasive alien species as agents of environmental change through newspaper articles, radio interviews and talk shows, and television coverage. Coverage of the C·I·B's activities has also extended to mainstream science journals such as *Nature* (Vol. 445, pp. 757-760) and *PLoS Biology* (Vol. 2, pp. 1701-1707). The full range of outputs would run to more than the length of this self-evaluation report alone, and in consequence a list of the popular articles and media interactions is available as part of the C·I·B's annual reports at http://www.sun.ac.za/cib/2008Review/. Several key features of information brokerage are illustrated in Box 18.

The limbovane outreach project, which is run entirely by women, has achieved considerable success. It is much lauded as *the* way to engage with teachers and learners in an outreach programme. The project, which has 13 schools at its core (but has developed a business plan for roll-out to many more), has interacted with a large number and wide range of learners, teachers and curriculum advisors (Box 18), predominantly from rural schools. By providing each school with two state-of-the-art microscopes, a notebook computer, lesson plans, keys, reference collections and professional assistance, the C·I·B is making a substantial difference to the way in which learners experience the Grade 10 FET curriculum. Moreover, the information gathered in transformed school sites and pristine areas nearby not only enables learners to research and understand the impacts of landscape transformation, but is also forming the core of a large-scale ant diversity assessment in the Western Cape and a central part of the C·I·B's long-term research on ant assemblage responses to change in the region and elsewhere across South Africa (Box 19).

Box 18 Information brokerage indicators

185	Conference presentations	25	Plenary and keynote addresses at international meetings
		11	Plenary and keynote addresses at local meetings
		45	International conference presentations
		66	National conference presentations
		11	International poster presentations
		27	National poster presentations
11	Conferences hosted	5	International
		6	Local
limbovane outreach project:			
13	limbovane schools	3400	Learners reached
		193	Teachers trained
		108	Interactions with learners
		66	Interactions with teachers
2.5	Years	6	Sampling seasons
		12	Conference presentations
		4	Poster presentations
		17	Popular articles/newsletters published
R1 444 102	Funds raised	R1 256 222	Donor funding
		R170 880	Core C·I·B funding
		R17 000	Prizes awarded

Box 19 The Iimbovane outreach project

Biodiversity rich, but resource poor countries need to allocate scarce resources to the competing goals of identifying and monitoring their biodiversity, and educating their populace about it; as mandated by the Convention on Biological Diversity. With basic existence the priority for many, often only relatively wealthy individuals become involved in biodiversity-related volunteering. In the Iimbovane outreach project, scientifically rigorous monitoring and public education is successfully combined. High school learners from 13 schools across the Western Cape participate in ant monitoring in transformed sites near their schools. They receive lessons on biodiversity using their own data and that of nearby pristine sites. In so doing, knowledge of biodiversity and the environment is integrated into the curriculum, addressing three major Learning Outcomes: 'Scientific inquiry and problem solving skills', 'Construction and application of life science knowledge' and 'Life sciences, technology, environment and society'. The project is undertaken in collaboration with the Western Cape Education Department (WCED), with whom the C·I·B works closely. The WCED identified the participating schools, which each received two microscopes and a notebook computer, as well as reference collections, lesson plans and instruction manuals and keys. In October and March each year, the Iimbovane team visits schools to help teachers and learners engage in the project. Not only is ant sampling undertaken, but learners are shown how to sample vegetation, use a microscope, produce a map, use a GPS hand-held receiver, and calculate diversity indices. Participation in a real study enhances the scholars' interest in science and direct interaction with scientists allows them to enquire about careers they might not otherwise have considered. The Darwin Initiative, which co-funds the project, has given it exceptional ratings. In addition to its outreach component, the Iimbovane project provides baseline data on an important insect group in a region where invertebrate monitoring is rare. These data are then integrated with the long-term data collected as part of the C·I·B's long-term research strategy.

Popular books have also been the outcome of the activities of the C·I·B and its core team members. A popular book on Gough Island was published in 2005, another on dragonflies and damselflies of South Africa that combines powerfully both popular and scientific information has just been published, and a third, on biological invasions more generally, is under consideration by Wits University Press. In its Foreword, Prof. Kadar Asmal, a previous South African Government Minister responsible for the inception of the Working for Water Programme, endorsed the work of the C·I·B, noting specifically:

'Part of my willingness to write this foreword is because Ms Leonie Joubert and the specialists at the Centre for Invasion Biology at the University of Stellenbosch are making this effort to make people, including leaders, aware of their responsibilities in terms of invasive alien species.'

All of the information generated by the C·I·B is archived, at the conclusion of research projects or student degree work, in the C·I·B IRSS. The system has a wide range of functionality, accepting files of many types and including metadata descriptions of all of them. The files are fully searchable and have been cross-linked and associated in ways appropriate to each of the projects and C·I·B core team members, post-doctoral associates and students responsible for them. The archive has appropriate dates for the release of the information, and typically those responsible for generating the data are notified when their data are requested by other users. Levels of access differ among users with the most basic level being open to the public. Presently the IRSS contains 170 research papers in portable document format (PDF) produced by core team members, students and post-doctoral associates. The IRSS also contains the theses and datasets of students who have graduated at the C·I·B. These documents are typically in MS Word, PDF or MS Excel format. The large majority of credit for the development of this system must go to the Stellenbosch University Library IT unit. However, the IRSS is an outcome of the C·I·B's interaction with the unit. Moreover, thanks to the demonstration of the utility of this system by the C·I·B, the DSPACE environment and its modification by Stellenbosch University are being adopted by the NRF as a vehicle for

information storage and retrieval at a national level. Internal documentation and temporary project files for collaborative studies are likewise stored in the DMS. Presently, the C·I·B has more than 10 634 working documents, images and data files stored on this system, including all of its student information and major reports. The IRSS and DMS are mirrored to a remote site, ensuring secure data storage for all aspects of the C·I·B operation.

5. Networking

5.1 Rationale

Scientific progress is realized in a variety of ways, from key breakthroughs by individuals to solutions generated through large, multidisciplinary collaborations. Nonetheless, communication of the outcomes and critical discussion thereof are an essential part of the process. As set out in the Introduction to this report, the C·I·B seeks to encourage a variety of approaches, and facilitates networking both among its members and with like-minded individuals and organizations in South Africa and abroad. In addition to these scientific collaborations, appreciation of the requirements of the broader community of knowledge users is essential. In consequence, networking has formed a critical component of the C·I·B's work. This has taken the form of formal agreements with research and other organizations, as well as with key individuals. In addition, informal networking by researchers is actively encouraged, and to prompt such networking considerable emphasis is also placed on the attendance of scientific meetings where prominent roles can be taken (such as keynote or plenary lectures). Early career researchers are encouraged to showcase their work to colleagues both domestically and abroad, and similar networking is encouraged among students, largely in the domestic science arena. Moreover, the C·I·B has also made special efforts to host international workshops and meetings to ensure that students can interact with some of the world's leading biodiversity scientists without incurring a substantial, and often unaffordable, cost.

The Elton Symposium, to be held in late 2008, is a prime example of the kind of meeting that will see many of the leading experts in invasion biology visit the C·I·B and interact with its members (see http://www.sun.ac.za/cib/events/Elton_CIB_symposium.htm).

5.2 Inputs

Internally, the C·I·B encourages networking in several ways. Each year, at least one joint team meeting is held (the ARM) at which all C·I·B members are expected to be present. Here, core team members, post-doctoral associates and post-graduate students are given an opportunity to showcase and discuss their work. The C·I·B Board's science advisors assess the quality of the work and provide input to the Board and Director on the strategic direction of the science. Typically, at least one international speaker is invited to provide a plenary at the meeting too (to date, Tim Blackburn, Peter Pyšek, Tom Stohlgren and Andrew Clarke). Non-academic staff members are expected to attend all sessions to provide them with added insight into the work being done by the Centre. In addition to these meetings, occasional workshops are held either on specific themes, usually as part of the research consortia formed within the C·I·B (e.g. on roads and rivers, or the Argentine ant), or covering matters of strategic importance to the C·I·B (e.g. scientific publication or risk analysis). Core team members are supported financially to attend the meetings and are expected to use a small amount of their students' running costs to help them attend.

In addition, the C·I·B hub communicates regularly and frequently with all C·I·B members either by e-mail or via the C·I·B home page (www.sun.ac.za/cib) which is updated on a regular basis. Interactions among core team members, to the benefit of students, are also encouraged by way of student co-supervision, and the provision of bench space for C·I·B students and post-doctoral associates across a range of institutions (e.g. Dr. Mark van Kleunen, a postdoctoral associate at UKZN, spent considerable time working at the C·I·B hub in 2006). Possibilities for

networking with the C·I·B are also discussed with a range of researchers at various institutions (in 2007 visits were made by the Director and Deputy Director: Operations to the following Universities: Fort Hare, Johannesburg, KwaZulu-Natal, Limpopo, Nelson Mandela Metropolitan, Pretoria, Rhodes, Walter Sisulu, Venda, Witwatersrand, Zululand).

The C·I·B makes a considerable effort to host workshops and symposia that ensure that students have an opportunity to interact with a range of scientists locally. In most cases, funding has to be solicited and reported on, and in all cases C·I·B staff time is used to organize, run and support the meetings.

5.3 Outputs

Since inception, the C·I·B has hosted a wide variety of meetings, and its members have presented work at a host of national and international meetings (Box 18). Highlights of the former include the multi-disciplinary, South African National Antarctic Programme (SANAP) symposium, hosted by the C·I·B on behalf of the NRF (October 2007), and a high-level workshop on the Argentine ant (July 2008). The SANAP Symposium drew together 'Antarctic' researchers, post-doctoral associates and students from across the country for the first time in nearly two decades. The Argentine ant workshop was attended by most of the world's experts working on this highly invasive species. Not only was the current status of knowledge reviewed, but a proposal for a joint, global project was developed. Notable plenary or keynote addresses include those by S.L. Chown to the King of Sweden and Delegates to the XXVIII Antarctic Treaty Consultative Meeting (2005) on biodiversity and alien species in Antarctica, D.M. Richardson's address at the 15th Australian Weeds Conference (2006) on management of riparian vegetation, and M.A. McGeoch's address to the Joint Ecological Society of America's meeting (2005) concerning the contribution of spatially explicit analysis to the understanding of species distributions. Many researchers visited C·I·B core team members too, with highlights including the sabbatical period of Prof. David Currie (McGill University, Canada) at the C·I·B hub for six months in 2007.

Box 20 Networking indicators

74	Joint venture training initiatives	44	Co-supervised students
		16	Biodiversity Conservation Academy students (2006)
		14	Biodiversity Conservation Academy students (2008)
9	Institutional partnerships developed	3	International
		5	Local
		1	In progress

Several major memoranda for collaborative work were signed with organizations both domestically and abroad (Box 20), including the BIOME Group at the University of Sheffield (UK), CapeNature, Iziko Museums of Cape Town, Center for Advanced Studies in Ecology and Biodiversity (CASEB, Chile), Institute for Biological Invasions (USA), SAIAB, SANParks and WfW. The agreement with CASEB resulted in a group of researchers from the C·I·B visiting Chile to attend the 3rd Binational Ecology Meeting of Chile and Argentina (Sept. 2007), and to seek further collaborations with colleagues from the region. CASEB scientists also paid several visits to the C·I·B from 2005 to 2008. A close working relationship has also developed with WfW. Co-funded work on the genetics of invasions and on the impacts of invasions and their remediation has commenced, with this work forming the impetus for the establishment of a molecular genetics laboratory in collaboration with the Stellenbosch University Department of Botany and Zoology. The development of a formal relationship with SANBI has also been set in motion, with the expectation that one (or possibly more) staff members will be accommodated within the C·I·B to work on invasion-related projects in collaboration with C·I·B researchers and students. SANBI interns will be accommodated within the Biodiversity Conservation Academy from 2009 onwards.

Internal networking and external networking with tertiary institutions has resulted in a range of collaborative activities (Box 20). Thus, of the research papers produced by the C·I·B, 15% include multiple C·I·B core team members, 23% are led by post-doctoral associates in collaboration with their hosts, 11% by students, 34% with collaborators within South Africa external to the C·I·B, and 36% with collaborators abroad. Moreover, five open programme students and their supervisors have worked or are currently working with the C·I·B.

6. Service provision

6.1 Rationale

In the external service provision arena, the main goal of the C·I·B is to be valued for excellent service that is evidence-based, reliable, affordable and impartial. Moreover, clients should always be in a position to follow up on the service they have received in such a way that they derive the full benefit from the C·I·B services available. Whilst the C·I·B does provide service, it does not consider itself a consulting venture. Rather it provides service on the basis of the knowledge it generates in specific fields and in collaboration with those clients that seek advice from it. In this regard, the quality of the Centre's research, the reputation of its researchers, and the project management skills of its staff all form key elements of its service provision.

One consequence of the C·I·B's overall approach to service provision is that it has provided, and will continue to provide, service to government at low cost (and in some instances at no cost). The C·I·B undertakes service at no or low cost where the service is clearly in line with its overall vision '*to provide the scientific understanding required to reduce the rate and impacts of biological invasions in a manner that will improve the quality of life of all South Africans*.' Although service at no cost is not commonly provided, in some instances this is clearly of strategic importance. This means that the C·I·B is prepared to absorb the cost of such service internally. The most notable of these has been the provision of advice to the various working groups charged with the development of regulations for the National Environmental Management: Biodiversity Act. The C·I·B has provided service at no cost since 2004, and for a process that is still ongoing.

Core team members and post-doctoral associates also provide scientific services, both domestically and abroad, in the form of editorial support and reviews for journals, reviews for granting agencies and with a special arrangement to assist the NRF particularly, board memberships, committee work for various organizations, and internal committee service to their home institutions. In all cases the same values of excellence, professionalism and reliability are adhered to.

6.2 Inputs

Close ties are maintained with key stakeholders who may wish to make use of the C·I·B's services. To a considerable extent this is done via the membership of these stakeholders on the C·I·B Board (e.g. SANBI, WfW, Global Invasive Species Programme - GISP), as well as through ongoing interactions between C·I·B management and the leadership/senior management of these organizations. A particularly close relationship has been established and is maintained with the various elements contributing to the South African National Antarctic Programme (SANAP) because of the priority accorded to Antarctica by the DST's White Paper on Science and Technology and by its updated strategy for the period 2008-2018 (Antarctic and Southern Ocean work is explicitly included among the specifics of the Grand Challenges) (see http://www.dst.gov.za/publications-policies).

C·I·B core team members are also provided annually with a small core grant that is not only meant to catalyse further research income generation, and research, but also to enable the C·I·B to make use of the expertise of the core team members where required. The development of regulations for Chapter 5 (Alien and Invasive

Species) of the National Environmental Management: Biodiversity Act (NEM:BA) provides a specific example where several C·I·B members contributed, and continue to contribute, to the process by way of their expertise. Indeed, this process has absorbed a significant amount of C·I·B time and resources, given that it has spanned the full life of the Centre, has proven tremendously controversial, and has yet to be concluded. In the cases where service provision is undertaken at a cost, C·I·B staff or core team members provide project management skills and the infrastructure (intellectual, physical) to undertake the work. These items are usually costed into the proposals or tenders based on rates typical of those recommended within a South African context (e.g. by the South African Council for Natural Scientific Professions).

Scientific service provision is usually seen as part of the process of undertaking science. Although the rationale for so doing could be the matter of debate (especially given the lucrative business of publishing and the open access alternatives that are being proposed) generally core team members and post-doctoral associates contribute considerable time to reviewing and committee work, seeing this as a service without which, more generally, the global science system would not be able to function.

6.3 Outputs

The C·I·B has provided a wide range of service both domestically and abroad (Box 21). Locally, one of its major contributions has been to the development of the regulations for Chapter 5 of the NEM:BA. However it has also developed the new Environmental Management Plan for the Prince Edward Islands, provided an integrated view on the complex regulatory framework for genetically modified organisms in South Africa (Box 22), and addressed the complex issue of road reserves as areas that are managed partly as a major Extended Public Works Programme. Internationally, one of its largest contributions is the assistance it is providing to the GISP with the development of the Invasive Alien Species Indicator for the 2010 Biodiversity Target (agreed at the World Summit on Sustainable Development in 2002). Through the activities of the Director, the C·I·B is also indirectly providing considerable service to the Scientific Committee on Antarctic Research (SCAR), by representing SCAR annually at the Committee for Environmental Protection (CEP) of the Antarctic Treaty System, and by ensuring that the CEP is provided with the scientific advice it solicits from SCAR and/or which SCAR considers significant for management of the Antarctic Treaty area.

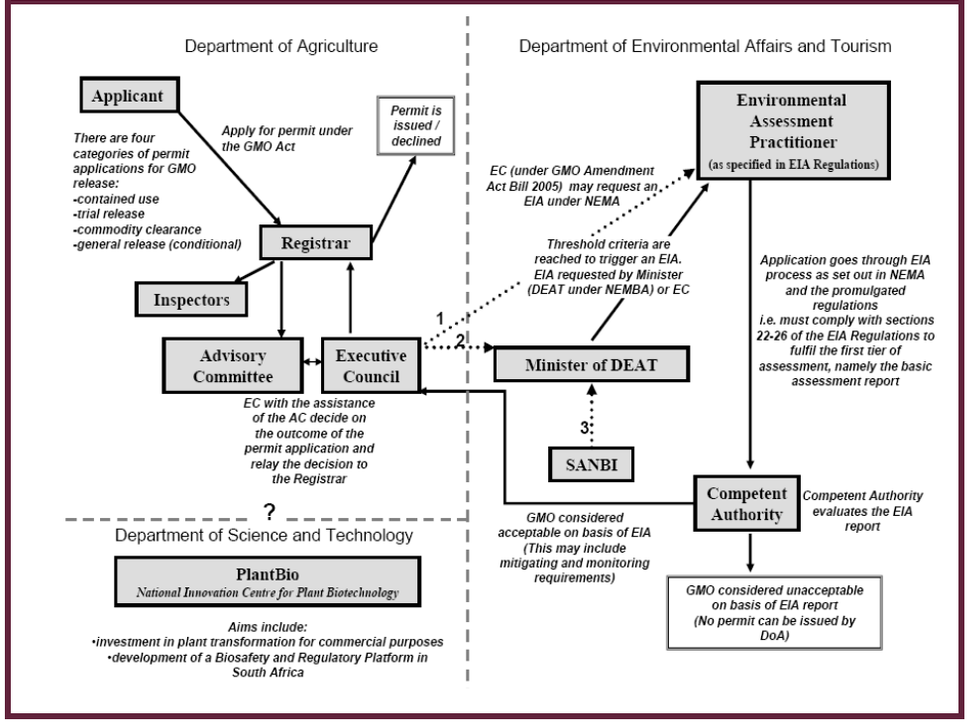
Box 21 Service provision indicators

6	Research contracts	4 Local 2 International
4	Policy advice interactions	NEM:BA Chapter 5, Invasive alien species NEM:BA Chapter 6, Threatened species GMOs: An assessment of the current policy framework for ecological risk assessment Road, power line and rail reserves: Towards best practice in management
80	Instances of service provision to NRF	66 NRF rating and proposal reviews conducted 14 Members served on NRF panels and committees (annually)
122	Panel and committee memberships (non-NRF)	76 National panel and committee representations 46 International panel and committee representations




From a scientific service provision perspective the C·I·B is heavily involved at a range of levels. Over the past four years core team members have functioned as Editors, Associate Editors and Editorial Board members of 22 international journals, specifically: *African Natural History*; *American Naturalist*; *Antarctic Science*; *Biodiversity and Conservation*; *Biological Invasions*; *BMC Ecology*; *Conservation Biology*; *Diversity and Distributions*; *Ecologia Mediterranea*; *Environmental Management*; *Functional Ecology*; *Global Ecology and Biogeography*; *International Journal of Wildland Fire*; *Journal of Applied Ecology*; *Journal of Arid Environments*; *Journal of Biogeography*; *Journal of Insect Conservation*; *Journal of Mammalogy; Journal of Orthoptera Research*; *Marine Biology; Odonatologica and PLoS One*. Locally, C·I·B core team members serve on the Editorial Boards of *African Zoology*; *Annals of the South African Museum*; *Koedoe*; *Navorsinge van die Nasionale Museum*; *Smithiana*; *South African Journal of Botany and South African Journal of Wildlife Research*. Many reviews have been undertaken for these and other local and international journals. Likewise, C·I·B core team members have provided and continue to provide reviews for a wide range of granting agencies, have been or are members of many NRF panels and committees (Box 21), and have also served or currently serve on the Boards of several organizations, such as SANBI, and the Center for Advanced Studies in Ecology and Biodiversity. Committee membership both locally and internationally is extensive and includes: Higher Education Resource Systems (HERS-SA), Census of Marine Life Programme (Africa Regional Implementation Committee) and several IUCN Species Survival Commission and Species Specialist Groups.

Box 22 Interpretation of the relationships between role players and the legal and policy framework governing the ERA process for GMOs in South Africa (see http://academic.sun.ac.za/cib/occasion.asp for details)



7. Management

In keeping with the reporting requirements, including the '*NRF Framework for Centres of Excellence in the South African National System of Research and Innovation*' (dated May 2003), this section provides an overview of the management of the Centre for Invasion Biology. In terms of the overall management and functioning of the C·I·B, reference is made to other significant documents available either as part of the review package or from http://www.sun.ac.za/cib/2008Review/.

7.1 Leadership and support

The C·I·B Director, Steven L. Chown, is a NRF A2-rated scientist (see www.nrf.ac.za for an explanation of this rating system), with an *h*-index of 31, and a considerable international profile in several research fields (conservation biology, ecology, entomology, evolutionary physiology, invasion biology, macroecology, and macrophysiology) and in the Antarctic policy arena. In a recent, independently conducted personnel assessment (© Cognadev 2008, Unique number Z977808), he was identified as ideally suited to integrate, manage and work within large, complex operations, with an eye for both the detailed business and how it should be integrated.

The Director is supported by a Deputy-Director Science Strategy (NRF A1 evaluated researcher Prof. David M. Richardson), who provides advice on strategic research issues, and a Deputy-Director: Operations (Sarah J. Davies), responsible for all operational aspects of the C·I·B, including assistance with implementation of the overall strategy.

In addition, the C·I·B comprises and is supported by an excellent academic and core staff. Dr. Cang Hui is presently the only other full-time academic in the Centre, and like Profs. Chown and Richardson, holds this post in association with the Department of Botany and Zoology at SU. The core staff comprises an additional 13 permanent and contract support staff, including both full-time and part-time personnel. Personnel management and integration of the C·I·B hub's activities takes place via one-on-one meetings, weekly meetings of the full staff complement, and through SU's performance management system. As part thereof, and to facilitate understanding of the roles of all staff members, and staff interactions, a comprehensive personnel plan has been developed for the core staff (http://www.sun.ac.za/cib/2008Review/). This plan sets out the qualifications, expectations and performance measures for both academic and non-academic staff of the hub. Staff members have ready access to the Director, and their concerns and expectations are addressed both informally and formally on an annual basis. Remuneration policy is set by Stellenbosch University, a system that generally works well, but has several inconsistencies that remain to be resolved.

In addition to these full meetings, the Director meets frequently (at least twice weekly) with the Deputy Director: Operations (originally the Research Manager, but the position is more complex than research management), and in a third meeting with the Deputy Director: Science Strategy and the Outreach Manager. These management meetings generally concern the way in which the strategic direction of the C·I·B is operationalized.

The Director is supported, and the performance of the C·I·B (and its Director) is assessed, annually and against its Service Level Agreements, by a 13-member Board comprising international research leaders in the field, stakeholders/partners in the South African biodiversity field, core team, staff and student representatives, and the primary funders (www.sun.ac.za/cib).

The C·I·B has an explicit focus on the biodiversity impacts of biological invasions but, as was made clear in the Introduction, has included in its strategy mechanisms to further knowledge of the foundations of variation in life across all its hierarchical levels.

7.2 Staffing

The C·I·B employs three academic staff (the molecular laboratory manager also has some duties in this regard), and even here the salary of one of them (the Director) is largely covered by the Department of Botany and Zoology. Two of the academic staff have high international profiles, whilst the third, a mathematical modeller with a wide interest in biology, contributes a skill scarce in South Africa. All of the other C·I·B researchers contribute some of their time to the C·I·B, but the C·I·B has no mandate to manage their time given that they are employees either of other departments at SU or other institutions. In drawing together the core team the rationale was, and remains, to include a diversity of skills, experience and approaches. The problem of the ageing cohort of white men that dominates South African science is unlikely to be resolved without core team membership including early career scientists from a range of groups. This rationale accounts for the present composition of the C·I·B core team (www.sun.ac.za/cib). Across the core team a wide variety of skills across a range of disciplines exists, so enabling the C·I·B to undertake a considerable scope of work and to educate students in a variety of fields. This work is highly considered internationally and locally, attested to by the award of several prizes to C·I·B members (e.g. the Hans Sigrist Award to D.M. Richardson, a UP Centenary Leading Minds medal to S.L. Chown, and an Academy of Science of South Africa Science-For-Society Gold Medal to M.J. Samways).

One area of work that remains the focus of special attention within the C·I·B stable, is the social sciences. This area required substantial initial assistance, but now is developing well as indicated by the research outputs. In addition, the C·I·B and partners (one C·I·B member and researchers in the humanities, a further natural scientist, and a Judge from the International Tribunal for the Law of the Sea) have applied for a large grant within the South African National Antarctic Programme, to provide a framework for social sciences research in this area, and has recently heard that its application has been successful. This grant provides for a full-time researcher, students and research assistance, and will also be used to help stimulate further interest in this field.

The core team members are well supported and have access to excellent student funding, post-doctoral associate support, and support for development via visits abroad and short courses. The C·I·B also has an open policy of considering proposals for consortia meetings and workshops at any time, and has supported a variety of these meetings which allow C·I·B members both to participate in and form research consortia. By encouraging international collaborative work, and highlighting the funding available via South Africa's science bilateral agreements, the C·I·B hub has managed to ensure that members can interact with a wide variety of researchers. This interaction and the further development of consortia is also promoted by invitation of plenary speakers to the ARM and by the support of various symposia. Short- and longer-term visitors to the C·I·B have included a wide range of high-profile international scientists such as Prof. Mark Burgman (Australian Centre of Excellence for Risk Analysis), Prof. Marcel Rejmánek (University of California, Davis) and Prof. Fabian Jaksic (CASEB, Pontificia Universidad Católica de Chile).

Collaborations and links with past students and post-doctoral associates have been maintained, largely through ongoing joint research and publication activities, and the further development of partnerships to address areas of interest common to the C·I·B and the new employers of past C·I·B members. Typically, C·I·B core team membership and staff turnover has been low. Three core team members have left, one to take up a position at the NRF, one after retirement, though still collaborating with Centre researchers and co-supervising students, and the other having resigned from the core team. The first database manager, two administrative officers, and a technician have left the Centre. Close ties are retained with the technician, but not with the other staff.

7.3 Institutional support

The C·I·B has had exceptional institutional support from SU. During the DST-NRF CoE competition process, SU provided additional support to S.L. Chown to ensure that he could participate fully without compromising his other activities. An undertaking was made that facilities would be provided to accommodate the C·I·B, and indeed once the Centre was awarded, more than R 1 million in building expenses was incurred to do so. SU provides ongoing support to the Centre through an annual cash award and the waiving of floor space charges (Box 23). In addition, management and administrative support have been exceptional. Through the office of the Vice-Rector: Research, and Research Development, the Centre's business has been accorded priority and exceptional attention. All administrative divisions at the University have provided excellent support, and the willingness of Finances, Human Resources and Research Development to discuss complex issues has been exceptional. In turn the C·I·B management has made a point of understanding the policy (SU and national) and legislative environments within which the University's managers and administrators must work and has endeavoured to ensure its compliance. In those cases where disagreements have arisen, an open, courteous relationship and a willingness on both sides to achieve a solution has been a characteristic of the relationship between the C·I·B and its host.

The interactions between the C·I·B and the various organizational and administrative components of SU are underwritten by the Memorandum of Agreement between the University and the NRF, by the Constitution and Rules of Procedure accepted by the SU Senate (via the Faculty of Science), and by a formal agreement between the C·I·B, the Dean of Science, and the Executive Head of the SU Department of Botany and Zoology, which forms the intellectual home of the C·I·B's three academics (S.L. Chown, D.M. Richardson, C. Hui, of which the former two hold Professorships in the Department). Through these agreements and appropriate discussion the C·I·B obtains considerable support in all the forms necessary (intellectual, management, administrative, infrastructural, financial, contractual, legal) for its business. Moreover, the C·I·B hub academics, post-doctoral associates and their students are accommodated within the intellectual and administrative environment of the Department of Botany and Zoology (the C·I·B does not host degree programmes in the sense that an academic Department does). This has meant substantial additional support for the C·I·B. Moreover, such support is also realized by core team members, post-doctoral associates and students at other Departments within SU, and at other institutions, by virtue of C·I·B membership. The C·I·B does not expect cash financial contributions for its membership, but realizes that its members achieve substantial in-kind support from their home institutions/organizations.

7.4 Location and facilities

Located at Stellenbosch University's main campus, the C·I·B central hub is well placed. It lies close to major research partners (CSIR Stellenbosch, SANBI's Kirstenbosch Research Centre, SANParks' Cape Research Centre, CapeNature Scientific Services) and is co-located with a variety of significant organizations (C.A.P.E., WWF, and biodiversity partners on the Kirstenbosch 'campus'). It is also within easy reach of the Universities of Cape Town and the Western Cape, as well as WfW and the Antarctica and Islands section of the DEAT (part of SANAP). It has well-established partnerships across a range of institutions in South Africa and is networked with them both electronically and through the activities of its core staff.

The facilities, including IT, infrastructure, equipment, media liaison and intellectual support (library etc.), provided by Stellenbosch University by way of the formal Memorandum of Agreement and associated documents (http://www.sun.ac.za/cib/2008Review/), are excellent. Moreover, these are available to C·I·B partners who visit the campus and increasingly through the internet. Financial support in the form of an annual grant (see 7.5 below) and floor space charge waivers are provided, and good leadership support in the form of ready access to management is also a feature of the interaction. The C·I·B is well integrated into the institutional plans, and is currently engaged in further

contributions to the SU's new Integrated Strategic Plan. Oversight by way of the University's policies and procedures is provided and guidance concerning these is provided by the appropriate staff (often at a senior level). C·I·B Board membership by the Dean of the Faculty of Sciences, and the Vice-Rector: Research (the Board Chair) ensures close integration of the C·I·B with University activities, as does the membership of both the Director and Deputy Director: Science Strategy of the Stellenbosch University Senate. In reporting through the Faculty of Science, the C·I·B Director has a direct communication line with management and is informed of all academic developments. The C·I·B also has a close, and formally agreed relationship (http://www.sun.ac.za/cib/2008Review/) with the Department of Botany and Zoology, on whose Management Committee S.L. Chown and D.M. Richardson serve.

7.5 Funding

The C·I·B has generated substantial income throughout its duration (Box 23), ranging from its central grant from the DST-NRF, to SU support, to various grants, contracts and awards to Centre members. It has maintained a generous attitude to funding to attract excellent students, and has also adopted a strategy of small 'core team member grants' to secure basic work on its behalf. Box 23 provides an analysis of the income and expenditure of the C·I·B over its existence, including all income that has been generated by the C·I·B hub and its three resident academics. It does not include all funds generated independently by its core team members because they also undertake work that is not part of the C·I·B's business (indeed contributions to the Centre in terms of time average about 10%).

Box 23 Funding and management indicators

R41 246 404	Income	R24 134 932	DST-NRF Centres of Excellence Programme
		R3 899 991	Other NRF
		R60 000	Other DST (jointly with Fitzpatrick CoE)
		R1 530 868	Other government
		R1 692 272	Other local sources
		R5 798 527	International sources
		R4 129 814	Stellenbosch University
17	Staff	3	Management
		1 + 3	Administrative (full-time + part-time)
		7 + 1	Technical (full-time + part-time)
		2	Research

7.6 Strategic positioning

Despite being formed *de novo* in 2004, the C·I·B has come to be recognized as an international leader in the field, and as a source of reliable, high quality human resources and advice. It has achieved this position through science and student excellence, directed networking with individuals and organizations in the same field, high quality service provision both domestically and abroad, and strategic vigilance. By pursuing a multi-level information brokerage and outreach strategy the significance of the C·I·B's work is now appreciated by a wide sector of the public, who are also better informed about the need to weigh carefully the benefits and costs of non-indigenous species, and the threats posed to biodiversity and the economy by biological invasions.




8. Prospectus

The Centre for Invasion Biology has been successful in developing rapidly to a position where it is considered *the* international Centre for such science, and for advice and assistance in the policy arena. The research strategy implemented and management model adopted for the core team, staff, post-doctoral associates and students has been effective at delivering research outcomes and services at a high level. Likewise, the strategy of partnerships has functioned well. The next phase of the C·I·B's work will involve a redevelopment of its strategy further to focus on three major areas. First, interactions among global change drivers, with invasions forming the core component thereof. These interactions are a major challenge not only for biodiversity conservation, but also for ensuring a sustainable future for all life[7,8]. Second, the ways in which genetic tools can help to provide the science required to reduce the rates and impacts of biological invasions. Third, to ensure additional take-up of C·I·B research in the policy arena. Whilst the participation in the development of regulations for the alien and invasive species chapter of the National Environmental Management: Biodiversity Act has enabled the C·I·B to transfer knowledge directly into policy, further connections between science and policy need to be developed. The growing number of policy appointments and declining primary research capacity in national agencies places a significant responsibility on institutions capable of delivering primary research and the human resources skilled to undertake it. The C·I·B's new strategy will include a focus on further ways to ensure the Centre's continuation beyond the 10-year lifespan originally envisaged in the CoE proposal calls. The C·I·B's partners and collaborators have made it clear that the research undertaken, the leadership provided in the field, the interactions with the community, and the policy advice provided can ill afford to be lost.

9. References in report

1. Cassey *et al*. 2005. *Austral Ecol*. 30, 475-480.
2. Kauffman. 1995. *At Home in the Universe*. Viking, London.
3. Ziman. 2007. *Science and Civil Society*. Imprint Academic, Exeter.
4. Medawar. 1982. *Pluto's Republic*. OUP, Oxford.
5. Ziman. 1978. *Reliable Knowledge*. CUP, Cambridge.
6. Gore. 2007. *The Assault on Reason*. Penguin Press, New York.
7. Brook *et al*. 2008. *Trends Ecol. Evol*. 23, 453-460.
8. Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-being: Biodiversity Synthesis*. World Resources Institute, Washington, D.C.

10. Appendix: Primary research papers

A. Biodiversity Foundations

A.1 Theory

Chown, S.L. & Gaston, K.J. (2008) Macrophysiology for a changing world. *Proceedings of the Royal Society of London B* **275**, 1469-1478.

Chown, S.L., Marais, E., Terblanche, J.S., Klok, C.J., Lighton, J.R.B. & Blackburn, T.M. (2007) Scaling of insect metabolic rate is inconsistent with the nutrient supply network model. *Functional Ecology* **21**, 282-290.

Chown, S.L., Sinclair, B.J., Leinaas, H.P. & Gaston, K.J. (2004) Hemispheric asymmetries in biodiversity - a serious matter for ecology. *PLoS Biology* **2**, 1701-1707.

Chown, S.L. & Storey, K.B. (2006) Linking molecular physiology to ecological realities. *Physiological and Biochemical Zoology* **79**, 314-323.

Chown, S.L. & Terblanche, J.S. (2007) Physiological diversity in insects: ecological and evolutionary contexts. *Advances in Insect Physiology* **33**, 50-152.

Currie, D.J. & Kerr, J.T. (2008) Tests of the mid-domain hypothesis: a review of the evidence. *Ecological Monographs* **78**, 3-18.

Deere, J.A. & Chown, S.L. (2006) Testing the beneficial acclimation hypothesis and its alternatives for locomotor performance. *American Naturalist* **168**, 630-644.

Gaston, K.J. & Chown, S.L. (2005) Neutrality and the niche. *Functional Ecology* **19**, 1-6.

Gaston, K.J., Chown, S.L. & Evans, K.L. (2008) Ecogeographical rules: elements of a synthesis. *Journal of Biogeography* **35**, 483-500.

Greve, M. & Chown, S.L. (2006) Endemicity biases nestedness metrics: a demonstration, explanation and solution. *Ecography* **29**, 347-356.

Marais, E. & Chown, S.L. (2008) Beneficial acclimation and the Bogert effect. *Ecology Letters* (in press) doi: 10.1111/j.1461-248.2008.01213.x

Parr, C.L., Sinclair, B.J., Andersen, A.N., Gaston, K.J. & Chown, S.L. (2005) Constraint and competition in assemblages: a cross-continental and modeling approach for ants. *American Naturalist* **165**, 481-494.

Prentis, P.J., Wilson, J.R.U., Dormontt, E.E., Richardson, D.M. & Lowe, A.J. (2008) Adaptive evolution in invasive species. *Trends in Plant Science* **13**, 288-294.

Pyšek, P., Richardson, D.M., Pergl, J., Jarošík, V., Sixtová, Z. & Weber, E. (2008) Geographical and taxonomic biases in invasion ecology. *Trends in Ecology and Evolution* **23**, 237-244.

Richardson, D.M. (2004) Plant invasion ecology - dispatches from the front line. *Diversity and Distributions* **10**, 315-319.

Richardson, D.M. & Pyšek, P. (2008) Fifty years of invasion ecology - the legacy of Charles Elton. *Diversity and Distributions* **14**, 161-168.

Richardson, D.M., Pyšek, P., Simberloff, D., Rejmánek, M. & Mader, A.D. (2008) Biological invasions - the widening debate: a response to Charles Warren. *Progress in Human Geography* **32**, 295-298.

Su, M., Zhang, Y., Hui, C. & Li, Z. (2008) The effect of migration on the spatial structure of intraguild predation in metapopulations. *Physica A* **387**, 4195-4203.

Terblanche, J.S., Janion, C. & Chown, S.L. (2007) Variation in scorpion metabolic rate and rate-temperature relationships: implications for the fundamental equation of the metabolic theory of ecology. *Journal of Evolutionary Biology* **20**, 1602-1612.

van Kleunen, M. & Burczyk, J. (2008) Selection on floral traits through male fertility in a natural plant population. *Evolutionary Ecology* **22**, 39-54.

van Kleunen, M., Lenssen, J.P.M., Fischer, M. & de Kroon, H. (2007) Selection on phenotypic plasticity of morphological traits in response to flooding and competition in the clonal shore plant *Ranunculus reptans*. *Journal of Evolutionary Biology* **20**, 2126-2137.

Willi, Y., Dietrich, S., van Kleunen, M. & Fischer, M. (2007) Inter-specific competitive stress does not affect the magnitude of inbreeding depression. *Evolutionary Ecology Research* **9**, 959-974.

Willi, Y., van Kleunen, M., Dietrich, S. & Fischer, M. (2007) Genetic rescue persists beyond first-generation outbreeding in small populations of a rare plant. *Proceedings of the Royal Society of London B* **274**, 2357-2364.

Zapata, F.A., Gaston, K.J. and Chown, S.L. (2005) The mid-domain effect revisited. *American Naturalist* **166**, E144-E148.

A.2. Behaviour

Do Linh San, E. & Somers, M.J. (2006) Mongooses on the move: an apparent case of interspecific cooperative vigilance between carnivores. *South African Journal of Wildlife Research* **36**, 201-203.

Nakin, M.D.V. & Somers, M.J. (2007) Shell availability and use by the hermit crab *Clibanarius virescens* along the Eastern Cape Coast, South Africa. *Acta Zoologica Academiae Scientiarum Hungaricae* **53**, 149-155.

Nel, J.A.J. & Somers, M.J. (2007) Distribution and habitat choice of Cape clawless otters, *Aonyx capensis*, in South Africa. *South African Journal of Wildlife Research* **37**, 61-70.

van Kleunen, M., Nanni, I., Donaldson, J.S. & Manning, J.C. (2007) The role of beetle marks and flower colour on visitation by monkey beetles (Hopliini) in the greater Cape Floral Region, South Africa. *Annals of Botany* **100**, 1483-1489.

A.3. Ecology

Belton, L.E., Dalerum, F. & van Rensburg, B.J. (2008) Factors associated with suni distribution in Tembe Elephant Park, South Africa; implications for management and

conservation of a small antelope. *African Journal of Ecology* (in press) doi: 10.1111/j.1365-2028.2008.00945.x.

Bowkett, A.E., Plowman, A.B., Stevens, J.R., Davenport, T.R.B. & Jansen van Vuuren, B. (2008) Genetic testing of dung identification for antelope surveys in the Udzungwa Mountains, Tanzania. *Conservation Genetics* (in press) doi: 10.1007/s10592-008-9564-7.

Dalerum, F., Somers, M.J., Kunkel, K.E. & Cameron, E.Z. (2008) The potential for large carnivores to act as biodiversity surrogates in southern Africa. *Biodiversity and Conservation* (in press) doi: 10.1007/s10531-008-9406-4.

Graf, J.A., Gusset, M., Reid, C., van Rensburg, S.J., Slotow, R. & Somers, M.J. (2006) Evolutionary ecology meets wildlife management: artificial group augmentation in the re-introduction of endangered African wild dogs (*Lycaon pictus*) *Animal Conservation* **9**, 398-403.

Gusset, M., Maddock, A.H., Gunther, G.J., Szykman, M., Slotow, R., Walters, M. & Somers, M.J. (2008) Conflicting human interests over the re-introduction of endangered wild dogs in South Africa. *Biodiversity and Conservation* **17**, 83-101.

Gusset, M., Ryan, S.J., Hofmeyr, M., van Dyk, G., Davies-Mostert, H.T., Graf, J.A., Owen, C., Szykman, M., Macdonald, D.W., Monfort, S.L., Wildt, D.E., Maddock, A.H., Mills, M.G.L., Slotow, R. & Somers, M.J. (2008) Efforts going to the dogs? Evaluating attempts to re-introduce endangered wild dogs in South Africa. *Journal of Applied Ecology* **45**, 100-108.

Gusset, M., Slotow, R. & Somers, M.J. (2006) Divided we fail: the importance of social integration for the re-introduction of endangered African wild dogs (*Lycaon pictus*) *Journal of Zoology* **270**, 502-511.

Keith, M., Chimimba, C.T., Reyers, B. & van Jaarsveld, A.S. (2007) A comparative analysis of components incorporated in conservation priority assessments: a case study based on South African species of terrestrial mammals. *African Zoology* **42**, 97-111.

Matthee, S., Horak, I.G., Beaucournu, J.C., Durden, L.A., Ueckermann, E.A. & McGeoch, M.A. (2007) Epifaunistic arthropod parasites of the four-striped mouse, *Rhabdomys pumilio*, in the Western Cape Province, South Africa. *Journal of Parasitology* **93**, 47-59.

Paul, I., van Jaarsveld, A.S., Korsten, L. & Hattingh, V. (2005) The potential global geographical distribution of Citrus Black Spot caused by *Guignardia citricarpa* (Kiely): likelihood of disease establishment in the European Union. *Crop Protection* **24**, 297-308.

Procheş, Ş., Forest, F., Veldtman, R., Chown, S.L., Cowling, R.M., Johnson, S.D., Richardson, D.M. & Savolainen, V. (2008) Dissecting the plant–insect diversity relationship in the Cape. *Molecular Phylogenetics and Evolution* (in press) doi:10.1016/j.ympev.2008.05.040.

Procheş, Ş., Wilson, J.R.U., Vamosi, J.C. & Richardson, D.M. (2008) Plant diversity in the human diet: weak phylogenetic signal indicates breadth. *Bioscience* **58**, 151-159.

Roberts, P.D., Somers, M.J., White, R.M. & Nel, J.A.J. (2007) Diet of the South African large-spotted genet *Genetta tigrina* (Carnivora, Viverridae) in a coastal dune forest. *Acta Theriologica* **52**, 45-53.

Samways, M.J. & Lu, S.-S. (2007) Key traits in a threatened butterfly and its common sibling: implications for conservation. *Biodiversity and Conservation* **16**, 4095-4107.

Trinkel, M., Ferguson, N., Reid, A., Reid, C., Somers, M., Turelli, L., Graf, J., Szykman, M., Cooper, D., Haverman, P., Kastberger, G., Packer, C. & Slotow, R. (2008) Translocating lions into an inbred lion population in the Hluhluwe-iMfolozi Park, South Africa. *Animal Conservation* **11**, 138-143.

Veldtman, R., McGeoch, M.A. & Scholtz, C.H. (2007) Can life-history and defence traits predict the population dynamics and natural enemy responses of insect herbivores? *Ecological Entomology* **32**, 662-673.

Walters, M., Milton, S.J., Somers, M.J. & Midgley, J.J. (2005) Factors affecting post-dispersal fate of seeds in an African savanna: an experimental approach. *South African Journal of Wildlife Research* **35**, 191-199.

Woodroffe, R., Davies-Mostert, H., Ginsberg, J., Graf, J., Leigh, K., McCreery, K., Mills, G., Pole, A., Rasmussen, G., Robbins, R., Somers, M.J. & Szykman, M. (2007) Rates and causes of mortality in Endangered African wild dogs *Lycaon pictus*: lessons for management and monitoring. *Oryx* **41**, 215-223.

Zietsman, J., Dreyer, L.L. & Esler, K.J. (2008) Reproductive biology and ecology of selected rare and endangered *Oxalis L.* (Oxalidaceae) plant species. *Biological Conservation* **141**, 1475-1483.

Zietsman, J., Dreyer, L.L. & Jansen van Vuuren, B. (2008) Genetic differentiation in *Oxalis* (Oxalidaceae): a tale of rarity and abundance in the Cape Floristic Region. *South African Journal of Botany* (in press) doi: 10.1016/j.sajb.2008.06.003.

A.4. Physiology

Chown, S.L., Marais, E., Picker, M.D. & Terblanche, J.S. (2006) Gas exchange characteristics, metabolic rate and water loss of the Heelwalker, *Karoophasma biedouwensis* (Mantophasmatodea: Austrophasmatidae) *Journal of Insect Physiology* **52**, 442-449.

Clusella-Trullas, S., Terblanche, J.S., Blackburn, T.M. & Chown, S.L. (2008) Testing the thermal melanism hypothesis: a macrophysiological approach. *Functional Ecology* **22**, 232-238.

Clusella-Trullas, S., Terblanche, J.S., van Wyk, J.H. & Spotila, J.R. (2007) Low repeatability of preferred body temperature in four species of Cordylid lizards: temporal variation and implications for adaptive significance. *Evolutionary Ecology* **21**, 63-79.

Gray, E.M. & Chown, S.L. (2008) Bias, precision and accuracy in the estimation of cuticular and respiratory water loss: a case study from a highly variable cockroach, *Perisphaeria* sp. *Journal of Insect Physiology* **54**, 169-179.

Klok, C.J. & Chown, S.L. (2005) Temperature- and body mass-related variation in cyclic gas exchange characteristics and metabolic rate of seven weevil species: broader implications. *Journal of Insect Physiology* **51**, 789-801.

Makarieva, A.M., Gorshkov, V.G., Li, B.L. & Chown, S.L. (2006) Size- and temperature-independence of minimum life-supporting metabolic rates. *Functional Ecology* **20**, 83-96.

Marais, E., Klok, C.J., Terblanche, J.S. & Chown, S.L. (2005) Insect gas exchange patterns: a phylogenetic perspective. *Journal of Experimental Biology* **208**, 4495-4507.

Sinclair, B.J. & Chown, S.L. (2005) Climatic variability and hemispheric differences in insect cold tolerance: support from southern Africa. *Functional Ecology* **19**, 214-221.

Sinclair, B.J. & Chown, S.L. (2006) Rapid cold-hardening in a Karoo beetle, *Afrinus* sp. *Physiological Entomology* **31**, 98-101.

Sinclair, B.J., Terblanche, J.S., Scott, M.B., Blatch, G.L., Klok, C.J. & Chown, S.L. (2006) Environmental physiology of three species of Collembola at Cape Hallett, North Victoria Land, Antarctica. *Journal of Insect Physiology* **52**, 29-50.

Terblanche, J.S., Deere, J.A., Clusella Trullas, S., Janion, C. & Chown, S.L. (2007) Critical thermal limits depend on methodological context. *Proceedings of the Royal Society of London B* **274**, 2935-2942.

Terblanche, J.S., Marais, E. & Chown, S.L. (2007) Stage-related variation in rapid cold hardening as a test of the environmental predictability hypothesis. *Journal of Insect Physiology* **53**, 455-162.

Terblanche, J.S., Sinclair, B.J., Klok, C.J., McFarlane, M.L. and Chown, S.L. (2005) The effects of acclimation on thermal tolerance, desiccation resistance and metabolic rate in *Chirodica chalcoptera* (Coleoptera: Chrysomelidae). *Journal of Insect Physiology* **51**, 1013-1023.

Terblanche, J.S., Tolley, K.A., Fahlman, A., Myburgh, K.H. & Jackson, S. (2005) The acute hypoxic ventilatory response: testing the adaptive significance in human populations. *Comparative Biochemistry and Physiology A* **140**, 349-362.

Terblanche, J.S., White, C.R., Blackburn, T.M., Marais, E. & Chown, S.L. (2008) Scaling of gas exchange cycle frequency in insects. *Biology Letters* **4**, 127-129.

White, C.R., Blackburn, T.M., Terblanche, J.S., Marais, E., Gibernau, M. & Chown, S.L. (2007) Evolutionary responses of discontinuous gas exchange in insects. *Proceedings of the National Academy of Sciences of the U.S.A.* **104**, 8357-8361.

White, C.R., Terblanche, J.S., Kabat, A.P., Blackburn, T.M., Chown, S.L. & Butler, P.J. (2008) Allometric scaling of maximum metabolic rate: the influence of temperature. *Functional Ecology* **22**, 616-623.

Worland, M.R., Leinaas, H.P. & Chown, S.L. (2006) Supercooling point frequency distributions in Collembola are affected by moulting. *Functional Ecology* **20**, 323-329.

A.5. Systematics

Foord, S.H. (2008) Cladistic analysis of the family Hersiliidae (Arachnida, Araneae) of the Afrotropical Region with the first records of *Murricia*, and the description of a new genus, *Prima*, from Madagascar. *Journal of Afrotropical Zoology* **4**, 111-141.

Grobler, J.P., Pretorius, D.M., Botha, K., Kotze, A., Hallerman, E.M. & Jansen van Vuuren, B. (2005) An exploratory analysis of geographic genetic variation in southern African nyala (*Tragelaphus angasii*) *Mammalian Biology* **70**, 291-299.

Hart, L., Chimimba, C.T., Jarvis, J.U.M., O'Riain, J. & Bennett, N.C. (2007) Craniometric sexual dimorphism and age variation in the South African Cape dune mole-rat (*Bathyergus suillus*) *Journal of Mammalogy* **88**, 657-666.

Joly, S., Stevens, M.I. & Jansen van Vuuren, B. (2007) Haplotype networks can be misleading in the presence of missing data. *Systematic Biology* **56**, 857-862.

Smit, H.A., Robinson, T.J. & Jansen van Vuuren, B. (2007) Coalescence methods reveal the impact of vicariance on the spatial genetic structure of *Elephantulus edwardii* (Afrotheria, Macroscelidea) *Molecular Ecology* **16**, 2680-2692.

B. Large-scale patterns in diversity

B.1. Abundance, occupancy and abundance structure

Hui, C. (2007) Negative correlation between dynamical complexity and metapopulation persistence: a reply. *Ecological Modelling* **200**, 271-272.

Hui, C. (2008) On species-area and species accumulation curves: a comment on Chong and Stohlgren's index. *Ecological Indicators* **8**, 327-329.

Hui, C. & McGeoch, M.A. (2007) Capturing the “droopy-tail” in the occupancy–abundance relationship. *Ecoscience* **14**, 103-108.

Hui, C. & McGeoch, M.A. (2007) Modeling species distributions by breaking the assumption of self-similarity. *Oikos* **116**, 2097-2107.

Hui, C. & McGeoch, M.A. (2007) A self-similarity model for the occupancy frequency distribution. *Theoretical Population Biology* **71**, 61-70.

Hui, C. & McGeoch, M.A. (2007) Spatial patterns of prisoner's dilemma game in metapopulations. *Bulletin of Mathematical Biology* **69**, 659-676.
Hui, C., McGeoch, M.A. & Warren, M. (2006) A spatially explicit approach to estimating species occupancy and spatial correlation. *Journal of Animal Ecology* **75**, 140-147.
Veldtman, R., McGeoch, M.A. & Scholtz, C.H. (2007) Fine-scale abundance and distribution of wild silk moth pupae. *Bulletin of Entomological Research* **97**, 15-27.
Warren, M., McGeoch, M.A., Nicolson, S.W. & Chown, S.L. (2006) Body size patterns in *Drosophila* inhabiting a mesocosm: interactive effects of spatial variation in temperature and abundance. *Oecologia* **149**, 245-255.

B.2. Spatial concordance in diversity and its temporal change

Boonzaaier, C., McGeoch, M.A. & Parr, C.L. (2007) Fine-scale temporal and spatial dynamics of epigaeic ants in Fynbos: sampling implications. *African Entomology* **15**, 1-11.
Botes, A., McGeoch, M.A. & Chown, S.L. (2007) Ground-dwelling beetle assemblages in the northern Cape Floristic Region: patterns, correlates and implications. *Austral Ecology* **32**, 210-224.
Botes, A., McGeoch, M.A., Robertson, H.G., van Niekerk, A., Davids, H.P. & Chown, S.L. (2006) Ants, altitude and change in the northern Cape Floristic Region. *Journal of Biogeography* **33**, 71-90.
Chown, S.L. & Convey, P. (2007) Spatial and temporal variabilities across life's hierarchies in the terrestrial Antarctic. *Philosophical Transactions of the Royal Society of London B* **362**, 2307-2331.
Chown, S.L., Hull, B. & Gaston, K.J. (2005) Human impacts, energy availability and invasion across Southern Ocean Islands. *Global Ecology and Biogeography* **14**, 521-528.
Currie, D.J. (2007) Disentangling the roles of environment and space in ecology. *Journal of Biogeography* **34**, 2009-2011.
Evans, K.L., Rodrigues, A.S.L., Chown, S.L. & Gaston, K.J. (2006) Protected areas and regional avian species richness in South Africa. *Biology Letters* **2**, 184-188.
Evans, K.L., van Rensburg, B.J., Gaston, K.J. & Chown, S.L. (2006) People, species richness and human population growth. *Global Ecology and Biogeography* **15**, 625-636.
Forest, F., Grenyer, R., Rouget, M., Davies, T.J., Cowling, R.M., Faith, D.P., Balmford, A., Manning, J.C., Procheş, Ş., van der Bank, M., Reeves, G., Hedderson, T.A.J. & Savolainen, V. (2007) Preserving the evolutionary potential of floras in biodiversity hotspots. *Nature* **445**, 757-760.
Greve, M., Gaston, K.J., van Rensburg, B.J. & Chown, S.L. (2008) Environmental factors, regional body size distributions, and spatial variation in body size of local avian assemblages. *Global Ecology and Biogeography* **17**, 514-523.
Hammond, W. & Griffiths, C. (2006) Biogeographical patterns in the fauna associated with southern African mussel beds. *African Zoology* **41**, 123-130.
Heelemann, S., Procheş, Ş., Rebelo, A.G., van Wilgen, B.W., Porembski, S. & Cowling, R.M. (2008) Fire season effects on the recruitment of non-sprouting serotinous Proteaceae in the eastern (bimodal-rainfall) fynbos biome, South Africa. *Austral Ecology* **33**, 119-127.
Hugo, S. & van Rensburg, B.J. (2008) The maintenance of a positive spatial correlation between South African bird species richness and human population density. *Global Ecology and Biogeography* **17**, 611-621.
Kark, S. & van Rensburg, B.J. (2006) Ecotones: marginal or central areas of transition? *Israel Journal of Ecology and Evolution* **52**, 29-53.
McGeoch, M.A., Schroeder, M., Ekbom, B. & Larsson, S. (2007) Saproxylic beetle diversity in a managed boreal forest: importance of stand characteristics and forestry conservation measures. *Diversity and Distributions* **13**, 418-429.
Procheş, Ş. (2005) The world's biogeographical regions: cluster analyses based on bat distributions. *Journal of Biogeography* **32**, 607-614.
Procheş, Ş. (2006) Latitudinal and longitudinal barriers in global biogeography. *Biology Letters* **2**, 69-72.
Procheş, Ş. & Cowling, R.M. (2006) Insect diversity in Cape fynbos and neighbouring South African vegetation. *Global Ecology and Biogeography* **15**, 445-451.
Procheş, Ş. & Cowling, R.M. (2007) Do insect distributions fit our biomes? *South African Journal of Science* **103**, 258-261.
Procheş, Ş., Cowling, R.M., Goldblatt, P., Manning, J.C. & Snijman, D.A. (2006) An overview of the Cape geophytes. *Biological Journal of the Linnean Society* **87**, 27-43.
Procheş, Ş., Wilson, J.R.U. & Cowling, R.M. (2006) How much evolutionary history in a 10x10 m plot? *Proceedings of the Royal Society of London B* **273**, 1143-1148.
Reyers, B. & McGeoch, M.A. (2007) A biodiversity monitoring framework for South Africa: progress and directions. *South African Journal of Science* **103**, 295-300.
Richardson, D.M. (2005) Diversity, distributions and conservation biogeography. *Diversity and Distributions* **11**, 1-2.
Richardson, D.M., Rouget, M., Ralston, S.J., Cowling, R.M., van Rensburg, B.J. & Thuiller, W. (2005) Species richness of alien plants in South Africa: environmental correlates and the relationship with indigenous plant species richness. *Ecoscience* **12**, 391-402.
Sinclair, B.J., Scott, M.B., Klok, C.J., Terblanche, J.S., Marshall, D.J., Reyers, B. & Chown, S.L. (2006) Determinants of terrestrial arthropod community composition at Cape Hallett, Antarctica. *Antarctic Science* **18**, 303-312.

Walther, B.A., Schaffer, N., van Niekerk, A., Thuiller, W., Rahbek, C. & Chown, S.L. (2007) Modelling the winter distribution of a rare and endangered migrant, the Aquatic Warbler *Acrocephalus paluidicola*. *Ibis* **149**, 701-714.

Wilson, J.W., van Aarde, R.J. & van Rensburg, B.J. (2007) Effects of habitat fragmentation on bird communities of sand forests in southern Mozambique. *Ostrich* **78**, 37-42.

Wilson, J.W., van Rensburg, B.J., Ferguson, J.W.H. & Keith, M. (2008) The relative importance of environment, human activity and space in explaining species richness of South African bird orders. *Journal of Biogeography* **35**, 342-352.

Yarnell, R.W., Scott, C.T., Chimimba, C.T. & Metcalfe, D.J. (2007) Untangling the roles of fire, grazing and rainfall on small mammal communities in grassland ecosystems. *Oecologia* **154**, 387-402.

B.3. Listing and mapping of invasive species

Baret, S., Rouget, M., Richardson, D.M., Lavergne, C., Egoh, B., Dupont, J. & Strasberg, D. (2006) Current distribution and potential extent of the most invasive alien plant species on La Réunion (Indian Ocean, Mascarene islands) *Austral Ecology* **31**, 747-758.

Chown, S.L., Sinclair, B.J. & Jansen van Vuuren, B. (2008) DNA barcoding and the documentation of alien species establishment on sub-Antarctic Marion Island. *Polar Biology* **31**, 651-655.

Jansen van Vuuren, B. & Chown, S.L. (2007) Genetic evidence confirms the origin of the house mouse on sub-Antarctic Marion Island. *Polar Biology* **30**, 327-332.

Laird, M.C. & Griffiths, C.L. (2008) Present distribution and abundance of the introduced barnacle *Balanus glandula* Darwin in South Africa. *African Journal of Marine Science* **30**, 93-100.

Lee, J.E. & Chown, S.L. (2007) *Mytilus* on the move: transport of an invasive bivalve to the Antarctic. *Marine Ecology Progress Series* **339**, 307-310.

Lee, J.E., Slabber, S., Jansen van Vuuren, B., van Noort, S. & Chown, S.L. (2007) Colonisation of sub-Antarctic Marion Island by a non-indigenous aphid parasitoid *Aphidius matricariae* (Hymenoptera, Braconidae) *Polar Biology* **30**, 1195-1201.

Midgley, G.F., Chown, S.L. & Kgope, B.S. (2007) Monitoring effects of anthropogenic climate change on ecosystems: a role for systematic ecological observation? *South African Journal of Science* **103**, 282.

Richardson, D.M. & Thuiller, W. (2007) Home away from home - objective mapping of high-risk source areas for plant introductions. *Diversity and Distributions* **13**, 299-312.

Robinson, T.B., Griffiths, C.L., McQuaid, C. & Rius, M. (2005) Marine alien species of South Africa - status and impacts. *African Journal of Marine Science* **27**, 297-306.

Robinson, T.B., Griffiths, C.L., Tonin, A., Bloomer, P. & Hare, M.P. (2005) Naturalized populations of Pacific oysters, *Crassostrea gigas* along the South African coast: distribution, abundance and population structure. *Journal of Shellfish Research* **24**, 443-450.

Tolley, K.A., Davies, S.J. & Chown, S.L. (2008) Deconstructing a controversial local range expansion: conservation biogeography of the painted reed frog (*Hyperolius marmoratus*) in South Africa. *Diversity and Distributions* **14**, 400-411.

van Jaarsveld, A.S., Pauw, J.C., Mundree, S., Mecenero, S., Coetzee, B.W.T. & Alard, G.F. (2007) South African Environmental Observation Network: vision, design and status. *South African Journal of Science* **103**, 289-294.

C. Determinants of invasion and scenarios of change

C.1. Determinants of plant invasion

Alston, K.P. & Richardson, D.M. (2006) The roles of habitat features, disturbance, and distance from putative source populations in structuring alien plant invasions at the urban/wildland interface on the Cape Peninsula, South Africa. *Biological Conservation* **132**, 183-198.

Foxcroft, L.C., Parsons, M., McLoughlin, C.A. & Richardson, D.M. (2008) Patterns of alien plant distribution in a river landscape following an extreme flood. *South African Journal of Botany* **74**, 463-475.

Foxcroft, L.C., Richardson, D.M. & Wilson, J.R.U. (2008) Ornamental plants as invasive aliens: problems and solutions in Kruger National Park, South Africa. *Environmental Management* **41**, 32-51.

Iponga, D.M., Milton, S.J. & Richardson, D.M. (2008) Soil type, microsite, and herbivory influence growth and survival of *Schinus molle* (Peruvian pepper tree) invading semi-arid African savanna. *Biological Invasions* (in press) doi: 10.1007/s10530-008-9221-6.

Kalwij, J.M., Robertson, M.P. & van Rensburg, B.J. (2008) Distribution of exotic plants along a steep altitudinal gradient is facilitated by anthropogenic activities. *Applied Vegetation Science* (in press) doi: 10.3170/2008-7-18555.

Milton, S.J., Wilson, J.R.U., Richardson, D.M., Seymour, C.L., Dean, W.R.J., Iponga, D.M. & Procheş, Ş. (2007) Invasive alien plants infiltrate bird-mediated shrub nucleation processes in arid savanna. *Journal of Ecology* **95**, 648-661.

Procheş, Ş., Wilson, J.R.U., Richardson, D.M. & Rejmánek, M. 2008) Searching for phylogenetic pattern in biological invasions. *Global Ecology and Biogeography* **17**, 5-10.

Pyšek, P. & Richardson, D.M. (2006) The biogeography of naturalization in alien plants. *Journal of Biogeography* **33**, 2040-2050.

Rambuda, T.D. & Johnson, S.D. (2004) Breeding systems of invasive alien plants in South Africa: does Baker's rule apply? *Diversity and Distributions* **10**, 409-416.

Richardson, D.M. (2006) *Pinus*: a model group for unlocking the secrets of alien plant invasions? *Preslia* **78**, 375-388.
Richardson, D.M. & Pyšek, P. (2006) Plant invasions: merging the concepts of species invasiveness and community invasibility. *Progress in Physical Geography* **30**, 409-431.
Richardson, D.M. & Rejmánek, M. (2004) Conifers as invasive aliens: a global survey and predictive framework. *Diversity and Distributions* **10**, 321-331.
Rouget, M., Richardson, D. M., Nel, J.L., Le Maitre, D.C., Egoh, B. & Mgidi, T. (2004) Mapping the potential ranges of major plant invaders in South Africa, Lesotho and Swaziland using climatic suitability. *Diversity and Distributions* **10**, 475-484.
Sharma, G.P. & Esler, K.J. (2008) Phenotypic plasticity among *Echium plantagineum* populations in different habitats of Western Cape, South Africa. *South African Journal of Botany* (in press) doi: 10.1016/j.sajb.2008.04.006.
Thuiller, W., Richardson, D.M., Pyšek, P., Midgley, G.F., Hughes, G.O. & Rouget, M. (2005) Niche-based modelling as a tool for predicting the risk of alien plant invasions at a global scale. *Global Change Biology* **11**, 2234-2250.
Thuiller, W., Richardson, D.M., Rouget, M., Procheş, Ş. & Wilson, J.R.U. (2006) Interactions between environment, species traits, and human uses describe patterns of plant invasions. *Ecology* **87**, 1755-1769.
van Kleunen, M. & Fischer, M. (2008) Adaptive rather than non-adaptive evolution of *Mimulus guttatus* in its invasive range. *Basic and Applied Ecology* **9**, 213-223.
van Kleunen, M., Fischer, M. & Johnson, S.D. (2007) Reproductive assurance through self-fertilization does not vary with population size in the alien invasive plant *Datura stramonium*. *Oikos* **116**, 1400-1412.
van Kleunen, M. & Johnson, S.D. (2007) Effects of self-compatibility on the distribution range of invasive European plants in North America. *Conservation Biology* **21**, 1537-1544.
van Kleunen, M. & Johnson, S.D. (2007) South African Iridaceae with rapid and profuse seedling emergence are more likely to become naturalized in other regions. *Journal of Ecology* **95**, 674-681.
van Kleunen, M., Johnson, S.D. & Fischer, M. (2007) Predicting naturalization of southern African Iridaceae in other regions. *Journal of Applied Ecology* **44**, 594-603.
van Kleunen, M., Manning, J.C., Pasqualetto, V. & Johnson, S.D. (2008) Phylogenetically independent associations between autonomous self-fertilization and plant invasiveness. *American Naturalist* **171**, 195-201.
van Kleunen, M. & Richardson, D.M. (2007) Invasion biology and conservation biology: time to join forces to explore the links between species traits and extinction risk and invasiveness. *Progress in Physical Geography* **31**, 447-450.
Wilson, J.R.U., Richardson, D.M., Rouget, M., Procheş, Ş., Amis, M.A., Henderson, L. & Thuiller, W. (2007) Residence time and potential range: crucial considerations in modelling plant invasions. *Diversity and Distributions* **13**, 11-22.
Wilson, J.R.U., Yeates, A., Schooler, S. & Julien, M.H. (2007) Rapid response to shoot removal by the invasive wetland plant, alligator weed (*Alternanthera philoxeroides*). *Environmental and Experimental Botany* **60**, 20-25.
Yelenik, S.G., Stock, W.D. & Richardson, D.M. (2007) Functional group identity does not predict invader impacts: differential effects of nitrogen-fixing exotic plants on ecosystem function. *Biological Invasions* **9**, 117-125.

C.2. Propagule pressure and Allee effects

Foxcroft, L.C. & Rejmánek, M. (2007) What helps *Opuntia stricta* invade Kruger National Park, South Africa: baboons or elephants? *Applied Vegetation Science* **10**, 265-270.
Foxcroft, L.C., Richardson, D.M., Rouget, M. & MacFadyen, S. (2004) Reconstructing fifty years of *Opuntia stricta* invasion in the Kruger National Park: environmental determinants and propagule pressure. *Diversity and Distributions* **10**, 427-437.
Procheş, Ş., Wilson, J.R.U., Veldtman, R., Kalwij, J.M., Richardson, D.M. and Chown, S.L. (2005) Landscape corridors: possible dangers? *Science* **310**, 779-781.
Somers, M.J., Graf, J.A., Szykman, M., Slotow, R. & Gusset, M. (2008) Dynamics of a small re-introduced population of wild dogs over 25 years: Allee effects and the implications of sociality for endangered species' recovery. *Oecologia* (in press) doi: 10.1007/s00442-008-1134-7.
Trakhtenbrot, A., Nathan, R., Perry, G. & Richardson, D.M. (2005) The importance of long-distance dispersal in biodiversity conservation. *Diversity and Distributions* **11**, 173-181.
van Kleunen, M. & Johnson, S.D. (2005) Testing for ecological and genetic Allee effects in the invasive shrub *Senna didymobotrya* (Fabaceae). *American Journal of Botany* **92**, 1124-1130.

C.3. Biological invasions, economically important species and climate change

Bomhard, B., Richardson, D.M., Donaldson, J.S., Hughes, G.O., Midgley, G.F., Raimondo, D.C., Rebelo, A.G., Rouget, M. & Thuiller, W. (2005) Potential impacts of future land use and climate change on the Red List status of the Proteaceae in the Cape Floristic Region, South Africa. *Global Change Biology* **11**, 1452-1468.
Jurenka, R., Terblanche, J.S., Klok, J.C., Chown, S.L. & Krafsur, E.S. (2007) Cuticular lipid mass and desiccation rates in *Glossina pallidipes*: interpopulation variation. *Physiological Entomology* **32**, 287-293.

Olwoch, J.M., van Jaarsveld, A.S., Scholtz, C.H. & Horak, I.G. (2007) Climate change and the genus *Rhipicephalus* (Acari: Ixodidae) in Africa. *Onderstepoort Journal of Veterinary Research* **74**, 45-72.

Terblanche, J.S. & Chown, S.L. (2006) The relative contributions of developmental plasticity and adult acclimation to physiological variation in the tsetse fly, *Glossina pallidipes* (Diptera, Glossinidae). *Journal of Experimental Biology* **209**, 1064-1073.

Terblanche, J.S. & Chown, S.L. (2007) The effects of temperature, body mass and feeding on metabolic rate in the tsetse fly *Glossina morsitans centralis*. *Physiological Entomology* **32**, 175-180.

Terblanche, J.S. & Chown, S.L. (2007) Factory flies are not equal to wild flies. *Science* **317**, 1678.

Terblanche, J.S., Clusella-Trullas, S., Deere, J.A. & Chown, S.L. (2008) Thermal tolerance in a south-east African population of the tsetse fly *Glossina pallidipes* (Diptera, Glossinidae): implications for forecasting climate change impacts. *Journal of Insect Physiology* **54**, 114-127.

Terblanche, J.S., Klok, C.J. & Chown, S.L. (2005) Temperature-dependence of metabolic rate in *Glossina morsitans morsitans* (Diptera, Glossinidae) does not vary with gender, age, feeding, pregnancy or acclimation. *Journal of Insect Physiology* **51**, 861-870.

Terblanche, J.S., Klok, C.J., Krafsur, E.S. & Chown, S.L. (2006) Phenotypic plasticity and geographic variation in thermal tolerance and water loss of the tsetse *Glossina pallidipes* (Diptera: Glossinidae): implications for distribution modelling. *American Journal of Tropical Medicine and Hygiene* **74**, 786-794.

C.4. Predictive invasion biology and the Argentine ant

Jumbam, K.R., Jackson, S., Terblanche, J.S., McGeoch, M.A. & Chown, S.L. (2008) Acclimation effects on critical and lethal thermal limits of workers of the Argentine ant, *Linepithema humile*. *Journal of Insect Physiology* **54**, 1008-1014.

C.5. Marine invasions and temporal change

Hampton, S.L. & Griffiths, C.L. (2007) Why *Carcinus maenas* cannot get a grip on South Africa's wave-exposed coastline. *African Journal of Marine Science* **29**, 123-126.

Robinson, T.B., Branch, G.M., Griffiths, C.L., Govender, A. & Hockey, P.A.R. (2007) Changes in South African rocky intertidal invertebrate community structure associated with the invasion of the mussel *Mytilus galloprovincialis*. *Marine Ecology Progress Series* **340**, 163-171.

Robinson, T.B., Griffiths, C.L., Branch, G.M. & Govender, A. (2007) The invasion and subsequent die-off of *Mytilus galloprovincialis* in Langebaan Lagoon, South Africa: effects on natural communities. *Marine Biology* **152**, 225-232.

D. Interactions between indigenous and invasive species

D.1. The Antarctic as a model system

Chown, S.L., Lee, J.E. & Shaw, J.D. (2008) Conservation of Southern Ocean Islands: invertebrates as exemplars. *Journal of Insect Conservation* **12**, 277-291.

Chown, S.L., Slabber, S., McGeoch, M.A., Janion, C. & Leinaas, H.P. (2007) Phenotypic plasticity mediates climate change responses among invasive and indigenous arthropods. *Proceedings of the Royal Society of London B* **274**, 2531-2537.

Davies, S.J., Chown, S.L. & Joubert, L.S. (2007) Renewed management system and provisions for South Africa's Sub-Antarctic Islands. *Papers and Proceedings of the Royal Society of Tasmania* **141**, 115-120.

Deere, J.A., Sinclair, B.J., Marshall, D.J. & Chown, S.L. (2006) Phenotypic plasticity of thermal tolerances in five oribatid mite species from sub-Antarctic Marion Island. *Journal of Insect Physiology* **52**, 693-700.

Frenot, Y., Chown, S.L., Whinam, J., Selkirk, P.M., Convey, P., Skotnicki, M. & Bergstrom, D.M. (2005) Biological invasions in the Antarctic: extent, impacts and implications. *Biological Reviews* **80**, 45-72.

Greve, M., Gremmen, N.J.M., Gaston, K.J. & Chown, S.L. (2005) Nestedness of Southern Ocean island biotas: ecological perspectives on a biogeographical conundrum. *Journal of Biogeography* **32**, 155-168.

Grobler, G.C., van Rensburg, L.J., Bastos, A.D.S., Chimimba, C.T. & Chown, S.L. (2006) Molecular and morphometric assessment of the taxonomic status of *Ectemnorhinus* weevil species (Coleoptera: Curculionidae, Entiminae) from the sub-Antarctic Prince Edward Islands. *Journal of Zoological Systematics and Evolutionary Research* **44**, 200-211.

Hugo, E.A., Chown, S.L. & McGeoch, M.A. (2006) The microarthropods of sub-Antarctic Prince Edward Island: a quantitative assessment. *Polar Biology* **30**, 109-119.

Jumbam, K.R., Terblanche, J.S., Deere, J.A., Somers, M.J. & Chown, S.L. (2008) Critical thermal limits and their responses to acclimation in two sub-Antarctic spiders: *Myro kerguelenensis* and *Prinerigone vagans*. *Polar Biology* **31**, 215-220.

Klok, C.J. & Chown, S.L. (2005) Inertia in physiological traits: *Embryonopsis halticella* caterpillars (Yponomeutidae) across the Antarctic Polar Frontal Zone. *Journal of Insect Physiology* **51**, 87-97.

Lombard, A.T., Reyers, B., Schonegevel, L.Y., Cooper, J., Smith-Adao, L.B., Nel, D.C., Froneman, P.W., Ansorge, I.J., Bester, M.N., Tosh, C.A., Strauss, T., Akkers, T., Gon, O., Leslie, R.W. & Chown, S.L. (2007) Conserving pattern and process in the Southern Ocean: designing a Marine Protected Area for the Prince Edward Islands. *Antarctic Science* **19**, 39-54.

McGeoch, M.A., le Roux, P.C., Hugo, E.A. & Chown, S.L. (2006) Species and community responses to short-term climate manipulation: microarthropods in the sub-Antarctic. *Austral Ecology* **31**, 719-731.

Mortimer, E. & Jansen van Vuuren, B. (2007) Phylogeography of *Eupodes minutus* (Acari: Prostigmata) on sub-Antarctic Marion Island reflects the impact of historical events. *Polar Biology* **30**, 471-476.

Mortimer, E., McGeoch, M.A., Daniels, S.R. & Jansen van Vuuren, B. (2008) Growth form and population genetic structure of *Azorella selago* on sub-Antarctic Marion Island. *Antarctic Science* **20**, 381-390.

Myburgh, M., Chown, S.L., Daniels, S.R. & Jansen van Vuuren, B. (2007) Population structure, propagule pressure, and conservation biogeography in the sub-Antarctic: lessons from indigenous and invasive springtails. *Diversity and Distributions* **13**, 143-154.

Sinclair, B.J. & Chown, S.L. (2006) Caterpillars benefit from thermal ecosystem engineering by wandering albatrosses on sub-Antarctic Marion Island. *Biology Letters* **2**, 51-54.

Slabber, S. & Chown, S.L. (2005) Differential responses of thermal tolerance to acclimation in the sub-Antarctic rove beetle *Halmaeusa atriceps*. *Physiological Entomology* **30**, 195-204.

Slabber, S., Worland, M.R., Leinaas, H.P. & Chown, S.L. (2007) Acclimation effects on thermal tolerances of springtails from sub-Antarctic Marion Island: indigenous and invasive species. *Journal of Insect Physiology* **53**, 113-125.

D.2. Interactions across continental systems

Buckley, Y.M., Anderson, S., Catterall, C.P., Corlett, R.T., Engel, T., Gosper, C.R., Nathan, R., Richardson, D.M., Setter, M., Spiegel, O., Vivian-Smith, G., Voigt, F.A., Weir, J.E.S. & Westcott, D.A. (2006) Management of plant invasions mediated by frugivore interactions. *Journal of Applied Ecology* **43**, 848-857.

Iponga, D.M., Cuda, J.P., Milton, S.J. & Richardson, D.M. (2008) *Megastigmus* wasp damage to seeds of *Schinus molle*, Peruvian pepper tree, across a rainfall gradient in South Africa: implications for invasiveness. *African Entomology* **16**, 127-131.

Procheş, Ş., Wilson, J.R.U., Richardson, D.M. & Chown, S.L. (2008) Herbivores, but not other insects, are scarce on alien plants. *Austral Ecology* **33**, 691-700.

Raghu, S., Wilson, J.R.U. & Dhileepan, K. (2006) Refining the process of agent selection through understanding plant demography and plant response to herbivory. *Australian Journal of Entomology* **45**, 308-316.

Robinson, T.B., Branch, G.M., Griffiths, C.L. & Govender, A. (2008) Resilience and elasticity of intertidal communities in response to harvesting of the alien mussel *Mytilus galloprovincialis*. *Journal of Experimental Marine Biology and Ecology* **354**, 169-181.

Traveset, A. & Richardson, D.M. (2006) Biological invasions as disruptors of plant reproductive mutualisms. *Trends in Ecology & Evolution* **21**, 208-216.

Wilson, J.R.U., Ajuonu, O., Center, T.D., Hill, M.P., Julien, M.H., Katagira, F.F., Neuenschwander, P., Njoka, S.W., Ogwang, J., Reeder, R.H. & Van, T. (2007) The decline of water hyacinth on Lake Victoria was due to biological control by *Neochetina* spp. *Aquatic Botany* **87**, 90-93.

Wilson, J.R.U., Rees, M. & Ajuonu, O. (2006) Population regulation of a classical biological control agent: larval density dependence in *Neochetina eichhorniae* (Coleoptera: Curculionidae), a biological control agent of water hyacinth *Eichhornia crassipes*. *Bulletin of Entomological Research* **96**, 145-152.

D.3. Honeybee sub-specific dynamics

Beekman, M., Allsopp, M.H., Wossler, T.C. & Oldroyd, B.P. (2008) Factors affecting the dynamics of the honeybee (*Apis mellifera*) hybrid zone of South Africa. *Heredity* **100**, 13-18.

Jordan, L.A., Allsopp, M.H., Beekman, M., Wossler, T.C. & Oldroyd, B.P. (2008) Inheritance of traits associated with reproductive potential in *Apis mellifera capensis* and *Apis mellifera scutellata* workers. *Journal of Heredity* **99**, 376-381.

Jordan, L.A., Allsopp, M.H., Oldroyd, B.P., Wossler, T.C. & Beekman, M. (2007) A scientific note on the drone flight time of *Apis mellifera capensis* and *A.m. scutellata*. *Apidologie* **38**, 436-437.

Jordan, L.A., Allsopp, M.H., Oldroyd, B.P., Wossler, T.C. & Beekman, M. (2008) Cheating honeybee workers produce royal offspring. *Proceedings of the Royal Society of London B* **275**, 345-351.

E. Impacts of invasion

E.1. Impacts of invasion and remediation

Cassey, P., Blackburn, T.M., Duncan, R.P. & Chown, S.L. (2005) Concerning invasive species: reply to Brown and Sax. *Austral Ecology* **30**, 475-480.

Cilliers, C.D., Botha, A., Esler, K.J. & Boucher, C. (2005) Effects of alien plant management, fire and soil chemistry on selected soil microbial populations in the Table Mountain National Park, South Africa. *South African Journal of Botany* **71**, 211-220.

Cilliers, C.D., Esler, K.J. & Boucher, C. (2004) Effects of alien plant management and fire on soil seed banks and regeneration in the Cape Peninsula National Park, South Africa. *South African Journal of Botany* **70**, 705-712.

Coetzee, B.W.T., van Rensburg, B.J. & Robertson, M.P. (2007) Invasion of grasslands by silver wattle, *Acacia dealbata* (Mimosaceae), alters beetle (Coleoptera) assemblage structure. *African Entomology* **15**, 328-339.

Dijkstra, K.D.B., Samways, M.J. & Simaika, J.P. (2007) Two new relict *Syncordulia* species found during museum and field studies of threatened dragonflies in the Cape Floristic Region (Odonata: Corduliidae). *Zootaxa*, 19-34.

Esler, K.J., Holmes, P.M., Richardson, D.M. & Witkowski, E.T.F. (2008) Riparian vegetation management in landscapes invaded by alien plants: insights from South Africa. *South African Journal of Botany* **74**, 397-400.

Galatowitsch, S.M. & Richardson, D.M. (2005) Riparian scrub recovery after clearing of invasive alien trees in headwater streams of the Western Cape, South Africa. *Biological Conservation* **122**, 509-521.

Hobbs, R.J., Arico, S., Aronson, J., Baron, J.S., Bridgewater, P., Cramer, V.A., Epstein, P.R., Ewel, J.J., Klink, C.A., Lugo, A.E., Norton, D., Ojima, D., Richardson, D.M., Sanderson, E.W., Valladares, F., Vila, M., Zamora, R. & Zobel, M. (2006) Novel ecosystems: theoretical and management aspects of the new ecological world order. *Global Ecology and Biogeography* **15**, 1-7.

Holmes, P.M., Esler, K.J., Richardson, D.M. & Witkowski, E.T.F. (2008) Guidelines for improved management of riparian zones invaded by alien plants in South Africa. *South African Journal of Botany* **74**, 538-552.

Holmes, P.M., Richardson, D.M., Esler, K.J., Witkowski, E.T.F. & Fourie, S. (2005) A decision-making framework for restoring riparian zones degraded by invasive alien plants in South Africa. *South African Journal of Science* **101**, 553-564.

Iponga, D.M., Milton, S.J. & Richardson, D.M. (2008) Superiority in competition for light: a crucial attribute defining the impact of the invasive alien tree *Schinus molle* (Anacardiaceae) in South African savanna. *Journal of Arid Environments* **72**, 612-623.

Mgobozi, M.P., Somers, M.J. & Dippenaar-Schoeman, A.S. (2008) Spider responses to alien plant invasion: the effect of short- and long-term *Chromolaena odorata* invasion and management. *Journal of Applied Ecology* **45**, 1189-1197.

Parker-Allie, F., Richardson, D.M. & Holmes, P.M. (2004) The effects of past management practices for invasive alien plant control on subsequent recovery of fynbos on the Cape Peninsula, South Africa. *South African Journal of Botany* **70**, 804-815.

Pretorius, M., Esler, K.J., Holmes, P.M. & Prins, N. (2008) The effectiveness of active restoration following alien clearance in fynbos riparian zones and resilience of treatments to fire. *South African Journal of Botany* **74**, 517-525.

Richardson, D.M., Holmes, P.M., Esler, K.J., Galatowitsch, S.M., Stromberg, J.C., Kirkman, S.P., Pyšek, P. & Hobbs, R.J. (2007) Riparian vegetation: degradation, alien plant invasions, and restoration prospects. *Diversity and Distributions* **13**, 126-139.

Richardson, D.M. & Kluge, R.L. (2008) Seed banks of invasive Australian *Acacia* species in South Africa: role in invasiveness and options for management. *Perspectives in Plant Ecology Evolution and Systematics* **10**, 161-177.

Richardson, D.M., van Wilgen, B.W. & Nuñez, M.A. (2008) Alien conifer invasions in South America: short fuse burning? *Biological Invasions* **10**, 573-577.

Swift, C., Jacobs, S. & Esler, K.J. (2008) Drought induced xylem embolism in four riparian trees from the Western Cape Province: insights and implications for planning and evaluation of restoration. *South African Journal of Botany* **74**, 508-516.

Vosse, S., Esler, K.J., Richardson, D.M. & Holmes, P.M. (2008) Can riparian seed banks initiate restoration after alien plant invasion? Evidence from the Western Cape, South Africa. *South African Journal of Botany* **74**, 432-444.

E.2. Risk assessment and scenario planning

Foxcroft, L.C., Rouget, M. & Richardson, D.M. (2007) Risk assessment of riparian plant invasions into protected areas. *Conservation Biology* **21**, 412-421.

McGeoch, M.A., Chown, S.L. & Kalwij, J.M. (2006) A global indicator for biological invasion. *Conservation Biology* **20**, 1635-1646.

McGeoch, M.A. & Pringle, K.L. (2005) Science and advocacy: the GM debate in South Africa. *South African Journal of Science* **101**, 7-9.

Mgidi, T.N., Le Maitre, D.C., Schonegevel, L., Nel, J.L., Rouget, M. & Richardson, D.M. (2007) Alien plant invasions - incorporating emerging invaders in regional prioritization: a pragmatic approach for Southern Africa. *Journal of Environmental Management* **84**, 173-187.

van Wilgen, N.J., Richardson, D.M. & Baard, E.H.W. (2008) Alien reptiles and amphibians in South Africa: towards a pragmatic management strategy. *South African Journal of Science* **104**, 13-20.

E.3. Ecosystem service

Bernhardt, E., Bunn, S.E., Hart, D.D., Malmqvist, B.T., Muotka, T., Naiman, R.J., Pringle, C., Reuss, M., and van Wilgen, B.W. (2006) The challenge of ecologically sustainable water management. *Water Policy* **8**, 475-479.

Bohensky, E.L., Reyers, B. & van Jaarsveld, A.S. (2006) Future ecosystem services in a Southern African river basin: a scenario planning approach to uncertainty. *Conservation Biology* **20**, 1051-1061.

Egoh, B., Reyers, B., Rouget, M., Richardson, D.M., Le Maitre, D.C. & van Jaarsveld, A.S. (2008) Mapping ecosystem services for planning and management. *Agriculture Ecosystems and Environment* **127**, 135-140.

Egoh, B., Rouget, M., Reyers, B., Knight, A.T., Cowling, R.M., van Jaarsveld, A.S. & Welz, A. (2007) Integrating ecosystem services into conservation assessments: a review. *Ecological Economics* **63**, 714-721.

Forsyth, G.G. & van Wilgen, B.W. (2008) The recent fire history of the Table Mountain National Park, and implications for fire management. *Koedoe* **50**, 3-9.

Govender, N., Trollope, W.S.W. & van Wilgen, B.W. (2006) The effect of fire season, fire frequency, rainfall and management on fire intensity in savanna vegetation in South Africa. *Journal of Applied Ecology* **43**, 748-758.

Kalwij, J.M., Milton, S.J. & McGeoch, M.A. (2008) Road verges as invasion corridors? A spatial hierarchical test in an arid ecosystem. *Landscape Ecology* **23**, 439-451.

Le Maitre, D.C., Milton, S.J., Jarmain, C., Colvin, C.A., Saayman, I. & Vlok, J.H.J. (2007) Linking ecosystem services and water resources: landscape-scale hydrology of the Little Karoo. *Frontiers in Ecology and the Environment* **5**, 261-270.

Richardson, D.M., Rundel, P.W., Jackson, S.T., Teskey, R.O., Aronson, J., Bytnerowicz, A., Wingfield, M.J. & Procheş, Ş. (2007) Human impacts in pine forests: past, present, and future. *Annual Review of Ecology, Evolution and Systematics* **38**, 275-297.

van Wilgen, B.W., Govender, N. & Biggs, H.C. (2007) The contribution of fire research to fire management: a critical review of a long-term experiment in the Kruger National Park, South Africa. *International Journal of Wildland Fire* **16**, 519-530.

van Wilgen, B.W., Govender, N. & MacFadyen, S. (2008) An assessment of the implementation and outcomes of recent changes to the fire management of the Kruger National Park. *Koedoe* **50**, 22-31.

van Wilgen, B.W., Nel, J.L. & Rouget, M. (2007) Invasive alien plants and South African rivers: a proposed approach to the prioritization of control operations. *Freshwater Biology* **52**, 711-723.

van Wilgen, B.W., Reyers, B., Le Maitre, D.C., Richardson, D.M. & Schonegevel, L. (2008) A biome-scale assessment of the impact of invasive alien plants on ecosystem services in South Africa. *Journal of Environmental Management* (in press) doi:10.1016/j.jenvman.2007.06.015.

van Wyk, E., Breen, C.M., Roux, D.J., Rogers, K.H., Sherwill, T. & van Wilgen, B.W. (2006) The Ecological Reserve: towards a common understanding for river management in South Africa. *Water SA* **32**, 403-409.

F. Social perceptions and invasions

F.1. Invasive species, community conservation and livelihoods

Dumalisile, L., Somers, M.J., Walters, M & Nel, J.A.J. (2005) Tourists' willingness to pay to view otters along the Wild Coast, South Africa: a potential for increased ecotourism. *The Journal for Transdisciplinary Studies in Southern Africa* **1**, 97-106.

Esler, K.J., Shackleton, L. & Chinsamy-Turan, A. (2006) SAWISE and HERS-SA: raising the profile of women in science. *South African Journal of Science* **102**, 275-276.

Krahulec, F., Leps, J. & Richardson, D.M. (2006) Marcel Rejmánek at 60 - the man and his work. *Preslia* **78**, 361-374.

Pyšek, P., Richardson, D.M. & Jarosik, V. (2006) Who cites who in the invasion zoo: insights from an analysis of the most highly cited papers in invasion ecology. *Preslia* **78**, 437-468.

Robinson, T.B., Branch, G.M., Griffiths, C.L. & Govender, A. (2007) Effects of experimental harvesting on recruitment of an alien mussel *Mytilus galloprovincialis*. *Journal of Experimental Marine Biology and Ecology* **345**, 1-11.

Robinson, T.B., Govender, A., Griffiths, C.L. & Branch, G.M. (2007) Experimental harvesting of *Mytilus galloprovincialis*: can an alien mussel support a small-scale fishery? *Fisheries Research* **88**, 33-41.

Samways, M.J. (2007) Rescuing the extinction of experience. *Biodiversity and Conservation* **16**, 1995-1997.

Sherwill, T., Arendse, L., Rogers, K., Sihlophe, N., van Wilgen, B., van Wyk, E. & Zeka, S. (2007) Stakeholder connectedness and participatory water resource management in South Africa. *Water SA* **33**, 505-512.

van Eeden, D.G., van Rensburg, B.J., De Wijn, M. & Bothma, J.D. (2006) The value of community-based conservation in a heterogeneous landscape: an avian case study from sand forest in Maputaland, South Africa. *South African Journal of Wildlife Research* **36**, 153-157.

Wilson, J.R.U., Procheş, Ş., Braschler, B., Dixon, E.S. & Richardson, D.M. (2007) The (bio)diversity of science reflects the interests of society. *Frontiers in Ecology and the Environment* **5**, 409-414.

Wilson, J.R.U., Procheş, Ş., Braschler, B., Dixon, E. & Richardson, D.M. (2008) Organismal complexity is an indicator of species existence value – the authors reply. *Frontiers in Ecology and the Environment* **6**, 299-300.

Winter, S.J., Prozesky, H. & Esler, K.J. (2007) A case study of landholder attitudes and behaviour toward the conservation of Renosterveld, a critically endangered vegetation type in Cape Floral Kingdom, South Africa. *Environmental Management* **40**, 46-61.