Centre for Statistics in Ecology, Environment and Conservation Report 2016

University of Cape Town

SEEC – Statistics in Ecology, Environment and Conservation

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1. Summary

1.1 Highlights of 2016

2016 was an eventful year for all in tertiary education, SEEC included, but nonetheless was still a very successful year for the group. At the start of the year we ran a planning workshop with the help of a professional dialogue facilitator, Peter Willis. This proved to be a most beneficial exercise, helping the group to identify four focus areas in which we intend to work in the future and for which we provide more detail later in this report.

Directly after the planning workshop we had our second Advisory Board meeting attended by our scientific advisers, Muthama Muasya and Bob Scholes. Our advisers were very pleased with the group's progress and also with the outcomes of the planning workshop, but also had useful advice on how to continue to grow SEEC as a research group.

In June we had our annual student symposium, which we held in the Postgraduate Centre in the Otto Beit building for the first time. This proved to be a very popular location, helping to attract researchers and students from outside of SEEC to the talks.

Overall 2016 was very productive from a research perspective, with the group publishing 49 scientific papers and two technical reports. Marc Burman, Greg Distiller, Dorine Jansen, Chris Oosthuizen and Etienne Pienaar were all awarded their PhDs and Kyle Lloyd his Masters, so a most successful year for our students.

Our postdocs also had an excellent year with three SEEC members receiving awards to either continue as postdocs at SEEC (Natasha Karenyi who was awarded a Claude Leon postdoc fellowship and Tess Gridley who was successful in securing another year of funding on her Claude Leon fellowship) and Sanet Hugo who will sadly be leaving us, but for a well-earned position at the South African Institute for Aquatic Biodiversity in Grahamstown where she was awarded a Professional Development Programme (PDP) postdoc. We also welcomed Dominic Henry who will be leading a large component of the Karoo BioGaps project.

SEEC's senior researchers also had a busy year. Res Altwegg was awarded a UCT URC Launching Grant. Henning Winker was awarded a new position at the Department of Agriculture,

Fisheries and Forestry and Melvin Varughese was also awarded a new new position, at IBM South Africa. Fitsum Abadi took up a position as Assistant Professor in Applied Quantitative Ecology at the New Mexico State University in the USA.

On the conference front SEEC had a very busy year with a number of our members presenting at the 5th International Statistical Ecology Conference in Seattle and many SEEC students and researchers presenting at the locally-organised conference of the South African Statistical Association.

This year we made a big push to expand on outreach. First and foremost we made our presence on social media and the internet much greater; we started a SEEC Facebook page, which now has 107 followers, and our Twitter account has grown to have 248 followers. Our SEEC website has been up and running for over a year and now is also the repository for the slides and code for another new outreach initiative: SEEC's Stats Toolbox Seminars. This year we had four Stats Toolbox Seminars, each hosted by a different SEEC member and on a different statistical topic. The idea behind starting the seminars was to present on statistical techniques that are commonly used by researchers in the fields of ecology, environmental studies and conservation. The hope is that this will help make a broader audience aware of the expertise and activities of SEEC. So far this has been a highly successful initiative with every seminar being well attended by people from many different departments (and even other institutions).

Overall, SEEC performed well as a group in 2016 and it seems that we are on a trajectory to even greater heights.

1.2 The team

1.2.1 Core team

Fitsum Abadi	University of the Witwatersrand / New Mexico State University
Res Altwegg	UCT, Statistical Sciences (director)
Laura Blamey	UCT, Biological Sciences
David Borchers	University of St Andrews, SEEC Honorary Research Associate (HRA)
Allan Clark	UCT, Statistical Sciences
Jonathan Colville	South African National Biodiversity Institute, SEEC HRA
Greg Distiller	UCT, Statistical Sciences
Ian Durbach	UCT, Statistical Sciences / African Institute for Mathematical Sciences
Birgit Erni	UCT, Statistical Sciences
Astrid Jarre	UCT, Biological Sciences
Sue Kuyper	UCT, Administrator
Iain MacDonald	UCT, Actuarial Sciences
David Maphisa	South African National Biodiversity Institute, SEEC HRA
Silvia Mecenero	South African National Biodiversity Institute, SEEC HRA
Guy Midgley	Stellenbosch University
Peter Ryan	UCT, Biological Sciences
Jasper Slingsby	South African Environmental Observation Network, SEEC HRA
Les Underhill	UCT, Biological Sciences
Melvin Varughese	UCT, Statistical Sciences / IBM
Vernon Visser	UCT, Statistical Sciences
Henning Winker	Department of Agriculture, Fisheries and Forestry, SEEC HRA

1.2.2 Advisory board

SEEC has an advisory board consisting of Bob Scholes (University of the Witwatersrand), John Donaldson (South African National Biodiversity Institute), Francesca Little (UCT, HOD Statistical Sciences), Muthama Muasya (UCT, HOD Biological Sciences), and Anton Le Roex (UCT, Dean of the Science Faculty).

1.2.3 Postdocs

Tess Gridley	Statistical Sciences
Dominic Henry	Statistical Sciences
Sanet Hugo	Statistical Sciences
Natasha Karenyi	Statistical Sciences
Theoni Photopoulou	Statistical Sciences *and* Institute for Coastal and Marine Research, NMMU
Chevonne Reynolds	Biological Sciences
Francis Strobbe	Statistical Sciences *and* South African National Biodiversity Institute
Petra Sumasgutner	Biological Sciences
Kate Watermeyer	Biological Sciences
Florian Weller	Biological Sciences

1.2.4 Postgraduate students

Ph.D.

Gordon Botha	Statistical Sciences
Marc Burman	Biological Sciences, graduated Dec 2016
Allan Clark	Statistical Sciences
Greg Distiller	Statistical Sciences, graduated Dec 2016
Greg Duckworth	Statistical Sciences
Dorine Jansen	Statistical Sciences, graduated June 2016
Emma Lockerbie	Biological Sciences
Alecia Nickles	Statistical Sciences
Chris Oosthuizen	University of Pretoria, graduated June 2016
Etienne Pienaar	Statistical Sciences, graduated Dec 2016
Kim Stevens	Biological Sciences
Zingfa Wala	Biological Sciences
Catherine Ward	Biological Sciences

M.Sc.

Francois Becker	Statistical Sciences
Danielle Boyd	Statistical Sciences
Francisco Cervantes Peralta	Statistical Sciences
Gciniwe Dlamini	Statistical Sciences
Qobo Dube	Statistical Sciences
Yolokazi Galada	Biological Sciences
Kyle Lloyd	Biological Sciences, graduated June 2016
Ariella Rink	Statistical Sciences
Zoe Woodgate	Biological Sciences

2. SEEC strategy and future focus areas

2.1 Intro -"Why we need a strategy and focus areas"?

The major goal of the planning workshop at the start of the year was to identify potential new areas of research for SEEC, which would not only help the group make a greater impact, but also enhance SEEC's collaborative methodologies, processes and potential. SEEC's premise is to act as a hub where ecologists and statisticians can tap into each other's skills in order to tackle problems that each specialist alone could not solve. We hoped that the workshop would foster new collaborations within the group and also increase our profile with our outside partners.

After extensive discussion at the planning workshop, the group decided to focus on four areas that we felt would help us achieve our goals. These are:
1. The 5 Big Questions
2. Interfacing
3. Outreach
4. Data analysis pipelines

2.2 "5 Big Questions"

In three short years SEEC has established itself as arguably the premier statistical ecology group in South Africa. However, as a group, we still feel that many researchers in South Africa, and even at UCT, are not aware of our existence or with what it is we actually do.

At the planning workshop we decided to identify five "big questions" as research priorities. We felt that this would help the group identify research areas where we could make a big difference and to help to focus SEEC's identity, both internally and for the outside world. Having a common research agenda would give us a basis for collaboration and applying for funding. Having an established identity and research agenda would also establish the relevance of SEEC's research in stakeholders' eyes and should also make it easier to say "no" to requests to work on peripheral issues.

Our initial plan, which we did in fact implement, was to ask SEEC members and affiliates to contribute what they felt were the most important research questions our group should be addressing.

We then collated this information to try identify common research themes. Overall, 33% of respondents felt the group should focus on global change, 16% on understanding and predicting species distributions, 12% on understanding biodiversity patterns and 11% on questions related to how scale affects inferences.

However, after consultation with our scientific advisers, it was decided that it is unnecessary to narrow the research focus of SEEC to these few research themes. Rather, these can be used to identify potential funding sources for collaborative projects and perhaps also to prioritise consultation work.

Overall, although this exercise was not used for its intended purpose, it was heartening to learn that despite the wide range of research fields in which SEEC's researchers work, there is some definite overlap in research interests. Going forward, we think that major research questions with common interest to many SEEC members will emerge with further engagement in exercises similar to the "5 big questions" questionnaire and with continued discussion of research in general.

2.3   Interfacing

The importance of interfacing was identified as a strategic area of development for SEEC at the Planning Workshop. In the circle of project acquisition and advice generation (See figure below), Clients (such as conservation organisations and governmental scientific working groups), will necessarily interact with the process of knowledge generation via two interfaces, irrespective of whether they are actively involved in the core knowledge generation process: from the perspective of SEEC, these are the "incoming" and the "outgoing" areas of interfacing.
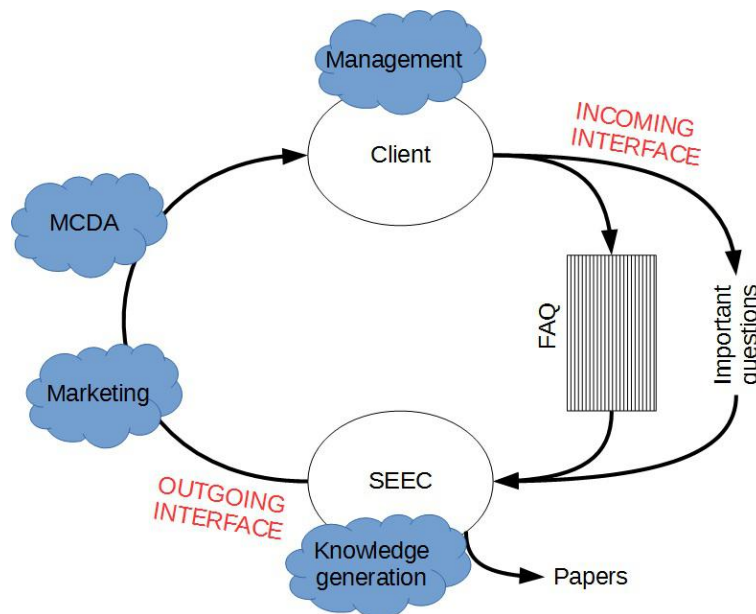
Through these interfaces, SEEC has the opportunity to do research and offer expertise in generating advice not only through producing information (through statistical data analysis and/or mathematical modelling), but also through embedding the process of the statistical/model output into a management process. The research field of Multiple Criteria Decision Analysis / Structured Decision Making is of particular relevance here. Expertise exists in the Statistical Sciences Department and, through two faculty members (Ian Durbach and Astrid Jarre), also in SEEC. There is

interest in strengthening this link between the Stats Department's Operations Research group and the conservation projects in Biological Sciences (as, for example, shown in the penguin pressure modelling process), and SEEC is in a strategic position to facilitate this process.

On the incoming area of interfacing with clients, SEEC should offer its expertise on actively embedding the results of the analyses into management processes along with its expertise in producing the desired information. SEEC realises that most of the time, this offer may be not taken up by the client, and this needs to be accepted. However, a process of inclusive, transparent, reproducible and accountable decision making process has in many cases led to better, and better accepted, decisions. It would be beneficial if incoming requests for knowledge generation would be reviewed by SEEC's Core group to agree on how best to offer the expertise the various members of SEEC can offer.

On the outgoing area of interfacing with clients, there may (or not) be the SEEC-led decision making process in which the results of analyses of SEEC (and probably elswhere) are embedded. However, an additional dimension in this area is to get the messages of SEEC research to the general public. It is recognised that the webpage and Twitter feeds currently in existence are likely inadequate for this goal. At the SEEC Strategic Planning Workshop, its was suggested to work with the Science Faculty's Marketing Group on how best to disseminate SEEC research products, including to journalists. The importance of multiple feedback loops between journalists and researchers was emphasised in order to support well-founded and balanced reporting to the general public.

2.4 Outreach

The prioritisation of SEEC's outreach activities was decided upon in order to showcase SEEC's work in statistical ecology and conservation and to better connect with the broader scientific community. The ultimate aim is to provide an educational service, foster collaboration and attract postgraduate students. During 2016, the first year of "SEEC Outreach", we achieved five basic short-term goals designed to launch the outreach section. Positive feedback from the various outreach projects identified areas where SEEC may have beneficial impact.

2.4.1 SEEC Stats Toolbox Seminars

The SEEC Stats Toolbox Seminars gives SEEC members the opportunity to present methods in statistical ecology using the growing supply of techniques and R packages. The aim is to provide a basic introduction to researchers working in ecology, environmental science and conservation, who may otherwise be unaware of new developments or who might need a refresher in established methods. The inaugural SEEC Stats Toolbox Seminar was held on 27 July 2016. The response was overwhelmingly positive, with attendance exceeding expectations (92 attendees from UCT, UWC, US and SANBI and other organisations) and numerous requests to make these seminars available countrywide or accessible online. Toolbox Seminars continued for the rest of 2016 on a monthly basis, with topics ranging from Species Distribution Models and Occupancy Models, to Distance Sampling and Handling Spatial Data. The R-code for each seminar was made available on the SEEC website, thereby increasing internet traffic to the website. Judging by the positive feedback from researchers and students, the Stats Toolbox seminars address an important need for more accessible instruction in statistical methods. We think that dedicated in-depth workshops on specific topics (See section 2.4.3) will meet these requirements more effectively. Therefore, Stats Toolbox seminars serve as a basic precursor for the workshops.

2.4.2   Social media

Our two social media platforms, Twitter and Facebook, have helped raise SEEC's profile locally as well as internationally. We post news about our research activities, news of members joining or leaving the group, our publications and we also retweet relevant science news. While our Facebook page is mainly used by individuals to follow our activities, our Twitter account is also followed by journals, funding bodies and research groups. Social media is a cheap and easy but hugely effective way of communicating our presence and identity.

2.4.3   Workshops

In March 2016, Ian Durbach and Theoni Photopoulou ran a 2.5 day workshop called Introduction to Statistical Modelling, covering an introduction to statistical inference (central limit theorem, distributions, confidence intervals) and statistical modelling (linear models, GLMs). It took place in Plettenberg Bay, kindly hosted by Greenbay College, a local school, between 10-12 March 2016. Twelve people with diverse backgrounds took part, ranging from interns at a local eco-tourism operator to MSc and PhD students as well as government employees.

Greg Distiller co-presented a 1 day Spatial Capture-Recapture (SCR) workshop on the 26th June 2016 in Seattle, U.S.A. An extended 3 day version of this workshop was also run from the 29th to the 31st August 2016 in St Andrews, UK.

2.4.4   Advisory boards

Greg Distiller was asked to serve on SANBI's scientific steering committee for leopard monitoring. The purpose of the committee is to verify that the science behind reports on leopard population monitoring is sound. These reports are written for the scientific authority that will ultimately use them to support decision-making on issues such as leopard harvest.

Astrid Jarre (SEEC), Lynne Shannon and Florian Weller (SEEC) work with the Seabird Technical Task Team at DEA to provide model-based input into African penguin conservation management, and to collaborate with members of the task team on data exchange, research project facilitation, and ongoing model development (currently focused on the penguin pressure model).

Henning Winker contributed to a report for the EU parliament on overfishing in EU waters. This report received considerable media interest and highlighted that most EU waters are not being managed sustainably and could produce much higher yields if better managed. The report is available here.

Birgit Erni and Theoni Photopoulou joined the Birds and Renewable Energy Specialist Group. This group consists of scientists from BirdLife South Africa, SANBI, the Endangered Wildlife Trust and environmental consultants working on renewable energy projects.

Res Altwegg serves on the steering committee for SANBI's BioGaps project and on the advisory board of the Animal Demography Unit.

2.4.5   Popular articles

Theoni Photopoulou's research on cookie-cutter sharks gained considerable media attention:
- The Real Jaws: Identifying the "demon whale-biter". Shark Focus, Issue 56, November 2016, pp.12-13

- UCT News. 20 June 2016. How the antics of cookie-cutter sharks sharpen our knowledge of migratory whales. https://www.uct.ac.za/dailynews/?id=9803
- Cape Argus. 27 April 2016. Migrating whales feel the bite of cookie-cutter sharks.
- New Scientist. 15 April 2016. Mysterious deep-sea sharks biting chunks out of migrating whales. https://www.newscientist.com/article/2084505-mysterious-deep-sea-sharks-biting-ch

Dr Sanet Hugo was also invited to contribute an article to Conversation Africa: What's on the to-do list for Africa's statistical ecologists? The Conversation Africa, 4 May 2016, http://theconversation.com/whats-on-the-to-do-list-for-africas-statistical-ecologists-58186

We have also contributed to a number of existing newsletters including those of SANCOR and SANBI.

2.4.6 Marketing materials

Dr Francis Strobbe created a pamphlet introducing SEEC's work and vision:
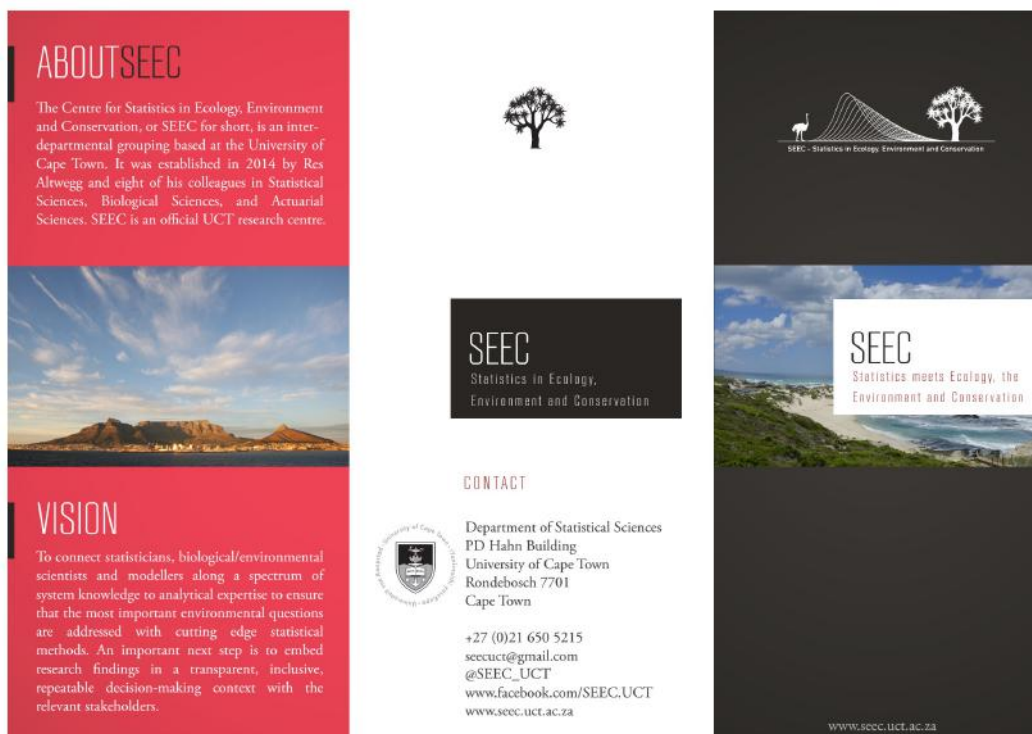
SEECTODAY

Recent developments in statistical methodology are making statistics ever more indispensable as a partner-discipline for the life sciences. The hybridisation between statistics and ecology is revolutionising the way ecological and environmental research is conducted, and at the same time presenting unique statistical problems and forging the further development of quantitative methods. This productive cycle has led to the emergent fields of statistical ecology and environmetrics.

The goal of these fields is to address core questions in ecology and environmental sciences using novel statistical approaches, which account for uncertainty more comprehensively and extract signals from noisy data more reliably. There is also an important role for decision support in ecology; to provide structured decision making in the face of uncertainty. This is leading to a far deeper understanding of natural systems. This understanding is the foundation for the sustainable use and management of pressures on biodiversity in the face of global change, and is the paradigm followed by SEEC.

RESEARCH
KEYSTONE

Develop methods and expertise to link data analysis and modelling to the conservation planning and management process. The statistical sciences develop quantitative tools for evaluating hypotheses in the light of data and therefore assume a critical role within science. This is complementary to the biological and environmental sciences, which study complex systems with large amounts of multi-layered data. In addition, research in this field supports decision making that directly affects human livelihoods and well-being as well as conservation priorities.

www.seec.uct.ac.za

WHYSEEC

South Africa is one of the 17 top mega-diversity countries in the world. The value of South Africa's biodiversity for the country's economy is well recognised: ecotourism is a large, growing area of employment that can be sustainable. A big proportion of the rural population depends on sustainable use of biodiversity while sustainability of the entire economy is predicated on the ecosystem services, like pollination or soil stabilisation, provided by a well-functioning environment.

"So far SEEC is the only dedicated statistical ecology research group in South Africa, but the hope is that many more such hubs of interdisciplinary research will grow and form an extensive national network that can jointly tackle some of the big questions of our times"

2.5   Data analysis pipelines

SEEC has recognised that there are many potential benefits of developing statistical computing work flows that pipeline data from their raw form to products that can be served on-line or similarly. Pipelines allow the analyses to be readily updated as new data come in. Where possible, we see great value in developing our analyses into data pipelines that can inform decision makers, highlight what SEEC is working on and make it accessible to a broader audience (and thus have greater impact) and enthuse or encourage data contributors (especially for citizen science initiatives). Developing data pipelines has several additional advantages for the research team in that the "back-end" requirements mean that the datasets and software code are clean and ready for additional analyses, and they serve to identify or highlight research gaps/needs.

Data pipelines may vary in scale and degree of detail from small apps showing live updates of citizen science data contributions, to more complicated apps that recalculate models every time data are uploaded to show citizen scientists the impact of their data contributions, to full-blown interactive apps that allow one to turn layers/datasets on and off and test the implications of including/excluding different data and sites. Obviously app development can be very time and effort intensive. Basic apps can be developed by researchers and students using readily available tools like RPubs and Shiny, but more complex apps will require dedicated input from (and funding for) software developers.

Existing SEEC projects in this sphere include a Drought Monitor presenting weather and stream flow rates from SAEON observation sites in the Jonkershoek Valley for the period 1961 to the present. There are many potential datasets and applications for which pipelines would be beneficial including trawl data, the South African Bird Atlas Project, the Coordinated Waterbirds Count Data and others.

3. Research and collaboration

3.1 SEEC research during 2016

Climate change

There are clear signs of climate change in southern Africa and we are aiming to understand how these changing are affecting biodiversity. For many species, we have very little data on where they occur. Raquel Garcia examined whether observed climate change could be used as a proxy to judge the risk to species with localised distributions by comparing how well these metrics match with projected range changes based on bioclimatic envelope models [15].

One class of organisms for which we have relatively good data are birds, with the Southern African Bird Atlas Project. Guillaume Péron found that several species of fire finches have changed their range and their brood parasites have followed suit. This resulted in new species compositions in places, creating opportunities for speciation among the brood parasitic indigobirds who are specific to a single host species. In other areas, closely related indigobird species now overlap and are at risk of hybridising [36].

Examining likely climatic changes over the last 140'000 years, we found that endemic bird species are most diverse in areas where the climate and the biomes are thought to have been most constant [20].

Similarly, Jonathan Colville, together with Richard Cowling (NMMU), Colin Beale (York University), Felix Forest (Kew Botanical Gardens), Brian Huntley (Durham University) and Res Altwegg are investigating how long-term climate and biome stability explain macro-gradients of contemporary and evolutionary diversity within the megadiverse Cape Floristic Region.

Ian Durbach and others re-examined whether the observed patterns of population decline in *Aloe dichotoma* was a sign of recent climate change or whether these trees are still reacting to changes that happened centuries ago [21].

Several species of dolphin have their habitat range end around Cape Town. Their distribution appears to be related to water temperature and consequently they may be affected by climate related habitat change. Tess Gridley is working in the Sea Search group with researchers from the University of Pretoria on an NRF funded project investigating the distribution of cetaceans within False Bay

and along the South Cape Coast. The ultimate aim is to understand how the distribution of these species is related to water temperate and how these species might be influenced changes in water temperate linked to climate change.

Species distribution modelling

One of the main aims in ecology is to understand why species occur where they do. Species distribution models (SDMs) are one of a number of statistical techniques that attempt to predict species distributions given a sample of species' occurrences. SDMs are typically used in situations where we have little to no information on where a species is absent, and where we only have one or a few repeat observations of a species.

In SEEC we are currently using SDMs for a number of species and purposes. Vernon Visser is currently working with Sea Search researchers Tess Gridley (also a member of SEEC) and Pauline Glotin on modelling the seasonal distributions of different cetacean species (whales and dolphins) in Namibia. Surprisingly, very little is known about the distributions of these large marine mammals in Namibian waters. Given that marine mining is widespread in Namibian seas, and very few areas are formally protected, it is imperative that we develop a better understanding of these charismatic species.

Qobo Dube (MSc student and SEEC member) is working with Sam Jack and Timm Hoffmann at the Plant Conservation Unit, UCT to develop SDMs for the iconic Quiver Tree *Aloidendron dichotomum* (until recently *Aloe dichotoma*). The survey data collected by the PCU includes counts across a number of age classes, so that Qobo has developed SDMs for multivariate binary and count data. He is supervised by Ian Durbach. Ian is also working with Kai Collins (University of Pretoria) using SDMs to investigate how future climate change might affect the distribution of the critically endangered riverine rabbit.

In another project Vernon Visser is collaborating with Conservation Biology Masters student Sarah Casola, SANBI researcher Krystal Tolley, and Cambridge University researcher Claire Spottiswoode, SDMs are being used for a very different purpose: to determine whether areas of high genetic diversity of two Cape frog species overlap with areas expected to experience major declines in habitat suitability.

In collaboration with partners from the SANBI Invasive Species Programme, the Centre for Invasion Biology at Stellenbosch University, and Sjirk Geerts at CPUT, SDMs are also being used to predict the potential distribution of invasive species in South Africa [16]. This is currently a widely used method for assessing the geographical distribution of risk of invasion by alien species, and for prioritising search and control strategies.

SDMs are highly dependent on reliable distribution data, but online sources such as the Global Biodiversity Information Facility (GBIF) often have data that are inaccurate (for various reasons, but including location errors, taxonomic issues, etc.). Together with Mark Robertson of the University of Pretoria and Cang Hui of Stellenbosch University, Vernon helped develop an R package "biogeo", which can be used to identify and correct some of these erroneous data. Their paper on this package came out in Ecography this year [37].

To estimate the global population size of a rare species, you first need to find out where it actually occurs. Francois Becker, under the supervision of Krystal Tolley, John Measey, Jasper Slingsby and Res Altwegg used a combination of species distribution models and capture-mark-recapture methods to find previously unknown populations of Rose's mountain toad (*Capensibufo rosei*) and estimate their total size. The result: there are only about 3000 individuals left and they

occur at three breeding sites within Table Mountain National Park.

Jonathan Colville, together with Colin Beale (York University), Felix Forest (Kew Botanical gardens) and Res Altwegg, are running SDMs for thousands of South African plant and animal species and are using these interpolated distributions in several different indices of diversity, including both taxonomic and evolutionary measures. This data is feeding into several projects, including delimiting biogeographic regions and understanding the macroecological patterns of South African biodiversity.

Occupancy models

Even though the bird atlas data are a particularly detailed data set, analyses using these data need to account for the fact that species are being overlooked in places where they actually occur. Occupancy models can correct for such false absences by modelling the observation process. Kristin Broms developed a model that can examine range expansions in much detail and applied it to the invasive common myna [4]. Since the models can be time-consuming to fit, especially in a Bayesian analysis, Allan Clark developed approximate methods that work well and are much faster [7].

Imperfect detection is also a big issue in the marine environment. Natasha Karenyi found that conservation targets can come out quite different if one accounts for imperfect detection, compared to ignoring the issue [23].

Investigating postreproductive lifespan in cetaceans

Life history is central to animals' ability to adapt to environmental change. Some female animals survive long past the cessation of their physiological capability for reproduction and may play the role of information custodians. Female humans, killer whales (*Orcinus orca*) and short-finned pilot whales (*Globicephala macrorhynchus*) have been shown to have extended postreproductive lifespans (PRLS). Theoni Photopoulou has been involved in a study of data from reproductive tissues and age-structure data from false killer whales (*Pseudorca crassidens*) to investigate the existence of PRLS in females of that species. This paper involved collaboration with the late Prof Peter Best from the Mammal Research Institute of the University of Pretoria and Prof Helene Marsh from James Cook University in Australia. The paper is currently in review with the journal Frontiers in Zoology and on arXiv .

Using hidden Markov models for animal acceleration data

Animal acceleration data is being collected more and more frequently with the continued miniaturisation of logging devices. The data that arise can be complex and large in volume. Classification algorithms and machine learning methods are often used to identify animal behaviours from acceleration data, but they do not account for the inherent serial dependence in the time series of the acceleration record. In addition, supervised learning is not often possible for wildlife data, when direct observation to ground-truth behaviours is difficult. Theoni Photopoulou was involved in a paper show-casing the use of hidden Markov models (HMM) for acceleration data, together with international colleagues and Megan Murgatroyd from the Percy FitzPatrick Institute for Ornithology. The paper was published in the journal Methods in Ecology and Evolution [28].

Patterns of cookie-cutter shark bitemarks on large whales

Most large whales and many other large marine animals bear the scars of bitemarks left by cookie-cutter sharks (*Isistius* spp.). Theoni Photopoulou worked with the late Prof Peter Best to investigate

patterns of scarring on large whales landed at Donkergat whaling station, South Africa, in 1963. The analysis used Generalized Additive Models (GAM) and confirmed (*Isistius* spp.) as the most likely biting agent and found a seasonal trend in the scarring on sei (*Balaenoptera borealis*), fin (*B. physalus*), offshore Bryde's (*B. brydeii* spp.) and sperm whales (*Physeter macrocephalus*). Their findings support what is currently hypothesized about the distribution and movements of these whale species and suggest that maturing sperm whales spend more time at high latitudes than fully mature males. The paper was published in the journal PLOS ONE [2].

Winter haul-out patterns in Weddell seals

Hauling out onto land or ice to rest, moult or breed is an essential life history component of seals and sea lions. Little is known about haul-out behaviour of Weddell seals in the Southern Weddell Sea. This area is covered in sea ice for most of the year. Animal-borne sensors were deployed on a total of 33 Weddell seals over three field seasons (2007, 2009, 2011) to describe observed behaviour and investigate the role of potential predictors for haul-out behaviour. Theoni Photopoulou was involved in the fieldwork and statistical analysis of this project together with researchers from the UK and US. Results showed a sexual segregation in time spent hauled out as well as the timing of haul-outs during the austral summer. These differences disappeared in winter when there was an increase in diving effort and a decline in time spent hauled out. The paper was published in the journal PLOS ONE [3].

Continuous-time Spatial Capture-Recapture (SCR)

SCR methods have become the industry standard for estimating and modelling animal distribution and density from capture-recapture data. To date all SCR models have been based on discretizing time, which requires aggregation of continuous time into discrete occasions. Historically, discrete occasion models have been adequate, but SCR surveys are increasingly conducted using devices that sample continuously in time and which "capture" individuals virtually without physically holding them. Greg Distiller's PhD research develops the first continuous-time framework for SCR surveys with such devices. It enables researchers to use detection time information to draw inferences about how animal activity patterns change over time – something that can't be done when time information is lost due to aggregation. The framework also leads to an estimator for the case in which detectors or traps are taken out of action by catching animals.

Karoo BioGaps project

Shale gas extraction in the Karoo remains a contentious issue given the potentially severe negative impacts on biodiversity in the region. A vast area of approximately 125000 km^2 has been earmarked for shale gas exploration. Patterns of biodiversity across the region therefore need to be quantified in order to support decision making regarding development. The Karoo biome has, however, traditionally been under-studied and so our understanding of its biodiversity remains limited. The South African National Biodiversity Institute (SANBI) has been tasked with addressing the biodiversity component of the strategic environmental assessment of shale gas development through the project entitled 'BioGaps: Filling the biodiversity information gaps to support development decision making in the Karoo'. The project aims to collect biodiversity data across 11 taxa (plants, mammals, fish, amphibians and reptiles, bees, dragonflies, orthoptera, scorpions, butterflies and spiders) within 50 study sites. In collaboration with SANBI and the field teams, Dominic Henry (a postdoctoral researcher who started with SEEC at the end of 2016) will be using the biodiversity data to develop

novel models that will allow for the identification of biodiversity hotspots and mapping of species richness. In addition to this Dominic will use species distribution and occupancy models to further understand the processes responsible for driving observed patterns of diversity across the Karoo.

Acoustic monitoring of animal density

Some animals are hard to find but easy to hear. We are working on methods that estimate animal density from acoustic data, using acoustic spatial capture-recapture (aSCR). These methods need an array of microphones. The pattern of detections and non-detections of individual calls on different microphones gives us information on how far the calls travel and their detection probability at different microphones. David Borchers and Res Altwegg, together with John Measey from the Centre for Invasion Biology developed these methods to monitor moss frog (*Arthroleptella lightfooti*) densities. This project is funded by a grant from the National Geographic Society. At the moment, we do not know which calls come from the same frog. Ian Durbach and Gciniwe Dlamini are developing machine learning algorithms to identify individual animals from the characteristics of their calls. Once these methods are working for frogs, we can combine them with aSCR, which would give us a tool to examine the ecology of moss frogs in much more detail. The methods could be used for other animals such as dolphins and crickets.

Tess Gridley has been working on blue skies behavioural questions related to sound production and function in cetaceans (with MSc student Anja Badenas and Simon Elwen, UP and Reshma Kassanjee UCT), as well as applied research questions investigating how acoustic signals can be used to monitor individual movement (with MSc student Rashley, 2016), population mixing (with MSc student St Clair-Hughes, 2016) and species assemblages (Erbs et al., accepted in JASA). The overall aim of this on going research is density estimation and movement monitoring using acoustic methods.

Balancing biodiversity and agriculture

Agriculture has revolutionised the planet's capacity to support humans, yet has simultaneously had a greater impact on biodiversity loss and land degradation than any other human activity. Balancing the demand for food with the conservation of biodiversity is one of the most pressing issues of our time. SEEC and FitzPatrick Institute post-doc, Chevonne Reynolds, addresses this trade-off using both field-based surveys and citizen science.

In collaboration with researchers from the University of Florida and University of Swaziland, Chevonne led a team of students to collect data on five taxonomic groups in the savanna-sugarcane mosaics of north-eastern Swaziland. The research was specifically designed to investigate how landscape heterogeneity in agricultural mosaics affects biodiversity, and which component of landscape heterogeneity, i.e., composition or configuration, is most influential. The results indicated that biodiversity responds to landscape composition, but that the responses differ across taxonomic groups in magnitude, direction and scale. This suggests that one-size-fits-all conservation strategies will not address the challenge of protecting biodiversity in agricultural landscapes, and that diverse, multi-scale strategies are of paramount importance. This research has already resulted in the submission of two manuscripts to peer-reviewed journals.

To address these questions at a larger scale, Chevonne is currently applying occupancy models to the SABAP2 dataset to investigate how bird population density responds to agricultural land-use. In collaboration with Res Altwegg (SEEC), Claire Spottiswoode (Fitz) and Andrew Balmford (University of Cambridge), she hopes to ascertain whether land-sharing or land-sparing is best for

protecting South African bird diversity in agricultural landscapes. Furthermore, the scale of this research, the multi-biome approach and the reliance on landscape structural metrics, as opposed to yield, suggest this project will provide novel insights into what is currently a hotly debated topic.

Sexual selection and speciation

The elaboration and diversification of sexually selected weapons remains a poorly understood, but very topical subject in evolutionary biology. The explosive adaptive radiation of monkey beetles, with over 750 species found in the greater Cape region, provides an ideal framework for testing the intensity of sexual selection and how weapon divergence can increase the tempo of speciation. Ariella Rink (SEEC MSc student), together with Jonathan Colville, Res Altwegg and Rauri Bowie (UC Berkeley) are investigating how sexual selection, together with natural selection, can explain patterns of monkey beetle diversity.

Functional ecology of insect pollinators

Many of South Africa's insect pollinators show highly specialized adaptations towards feeding on different floral resources. Together with researchers from the University of Vienna, Jonathan Colville is investigating the morphological adaptations of different insect pollinators and relating these to different floristic niches. These specializations are incorporated into measures of functional diversity, and linked to models explaining patterns of species diversity.

3.2 Research performance

3.2.1 Metrics of performance

In 2016 SEEC published a total of 49 papers, one report and one book chapter. This is eight more publications than in 2015 and equates to 2.43 publications per SEEC core member. The mean impact factor of journals in which SEEC members published was 3.21; there were eight papers in journals with an impact factor greater than five and two papers in Fish and Fisheries, which has an impact factor of 8.258.
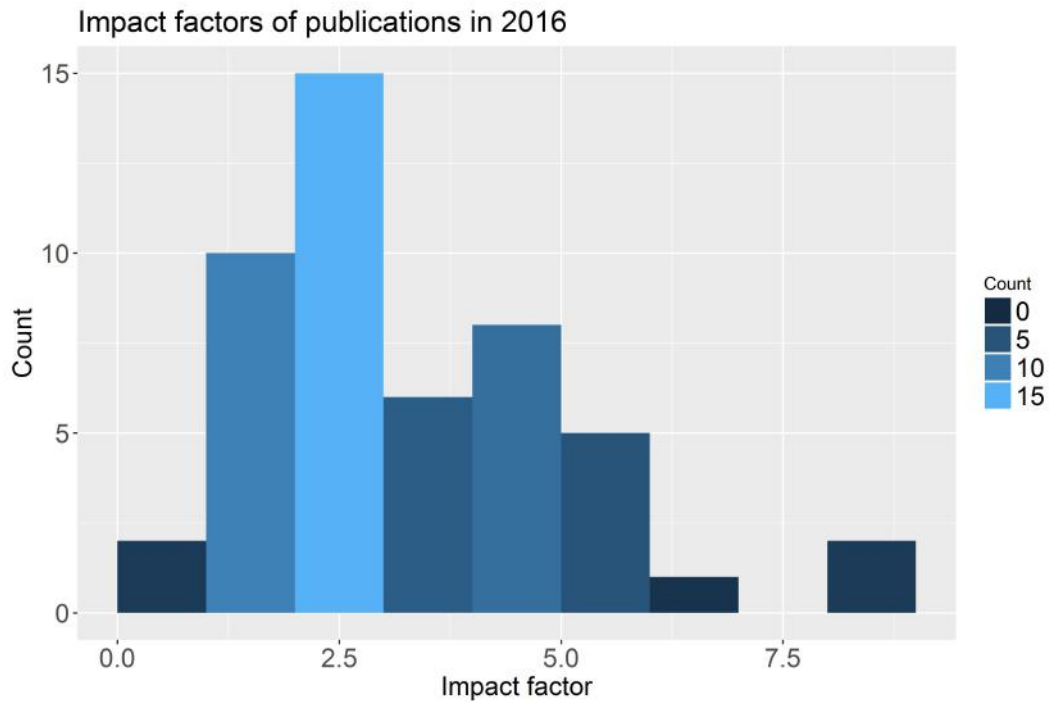

3.3 Co-publication

As a measure of current collaboration within the core team, we plotted 2016 publications that were co-authored between SEEC core members. In the figure below, each line between team member's names represent a joint publication.

Joint publications 2016
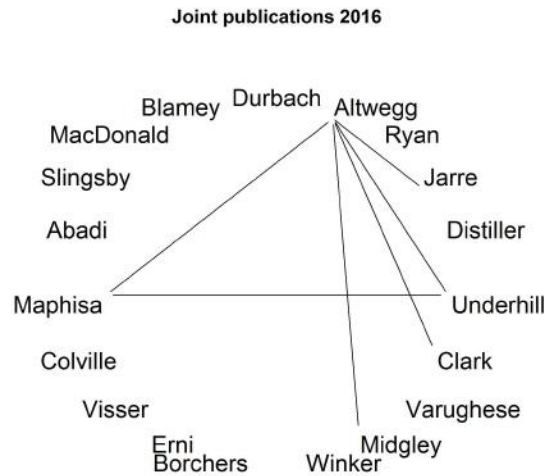
3.4 Student supervision

SEEC hosted 13 PhD and eight Masters students during 2016. Of these, five PhD students and one Masters student graduated during the year.

As another measure of collaboration within SEEC, we plotted co-supervision of postgraduate students (MSc and PhD). Thin lines connecting team member's names indicate joint supervision of one student; intermediate lines represent co-supervision of two students and the thick line represents co-supervision of three students.

Joint postgraduate mentorship
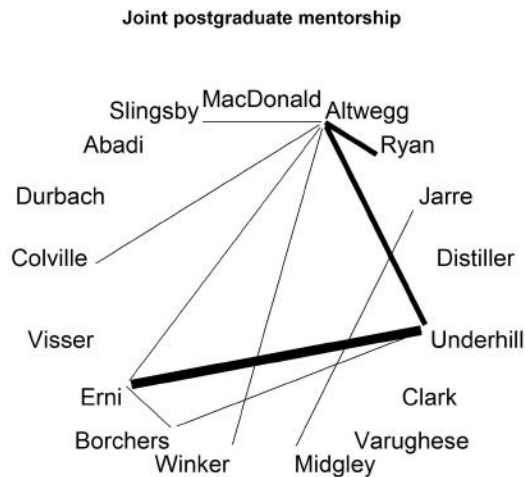
3.5 SEEC student symposium 2016

The 2016 SEEC Student Symposium was held in the Postgraduate Student Room in the Otto Beit building, which proved to be an excellent venue, being easily accessible for people on upper campus

and also boasting beautiful old paintings and wood-panelled walls.

This year Prof. Bob Scholes presented the plenary talk and gave a very interesting talk on metrics of change that are used to measure and record all aspects of global change.

We had a total of 20 talks from both postgrad students and postdocs. This year we introduced five minute speed talks for the postdocs as a way of getting feedback from these very important members of SEEC.

Overall, the symposium was a big success with high attendance from researchers and students outside of SEEC and we are hopeful of hosting the 2017 symposium at the same venue. Many thanks to Sue Kuyper for all her hard work in organising the symposium, and to all the speakers for making it a success.

4. Courses: Study design and data analysis

4.1 STA2007/STA5014

This course was developed by SEEC members, Birgit Erni, Theoni Photopoulou, Res Altwegg and Greg Distiller, in 2015 as an online course and is a welcome addition to the curriculum of biology and statistics students. The course aims to equip students with practical experience and skills in analysing data and using some statistical techniques frequently used in the sciences. The skills include designing experiments, choosing appropriate statistical methods for visual display and statistical modelling of data, model checking, interpretation and reporting of statistical results, and understanding limitations of statistical methods and data.

5. Partners

We have a strong network of partners at three levels: within UCT, nationally, and internationally.

5.1 Within UCT

Within UCT, SEEC has close links to a number of other research groups. Res Altwegg holds a research chair with the **African Climate and Development Initiative (ACDI)**. Astrid Jarre is affiliated with the **Marine Research Institute (MARE)**. SEEC core members Peter Ryan and Les Underhill are directors of the **Percy FitzPatrick Institute for African Ornithology** and the **Animal Demography Unit**, respectively. SEEC members also collaborate with a number of researchers in **Biological Sciences**, particularly with the **Plant Conservation Unit**.

5.2 National

A key partner outside UCT is the **South African National Biodiversity Institute**. Two of their scientists, Jonathan Colville and David Maphisa, are SEEC core members.

South African Environmental Observation Network's Jasper Slingby is a SEEC core member.

Guy Midgley from **Stellenbosch University**'s Department of Botany and Zoology is a SEEC core member. SEEC has several ongoing collaborations, and has signed a memorandum of understanding, with the **Centre for Invasion Biology** at the University of Stellenbosch.

SEEC members collaborate with Peter Taylor of the **University of Venda** who holds a South African Research Chair in Biodiversity and Change in the Vhembe Biosphere Reserve. SEEC has also been invited to teach statistical courses at this university.

We have a grant from the **Applied Centre for Climate and Earth Systems Science (ACCESS)** through the Ecosystems Services and Human Livelihoods theme. We also held discussions about collaborating with ACCESS on training courses in statistics.

SEEC member, Melvin Varughese, is now working for **IBM Research South Africa** in their Cognitive Astronomy group

We work with key conservation organisations: **Cape Nature**, the **Endangered Wildlife Trust**, and **BirdLife South Africa** on various projects.

5.3 International
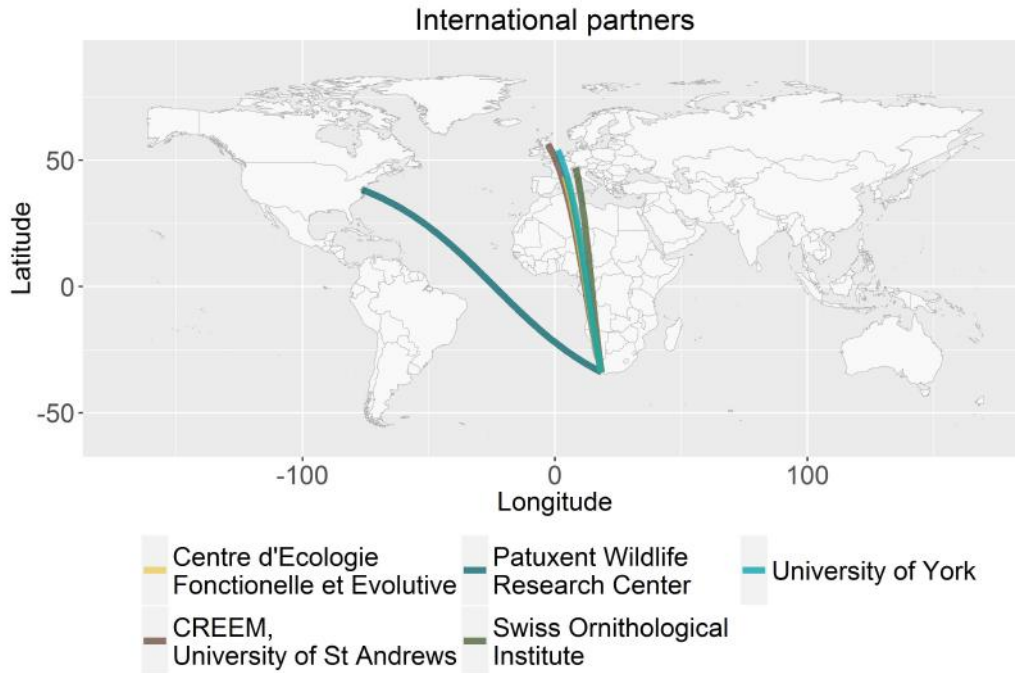
Internationally, we collaborate with some of the leading groups in our field. One of them is the **Centre for Research into Ecological and Environmental Modelling (CREEM)** at the University of St Andrews. David Borchers from CREEM is an Honorary Research Associate at SEEC and the main link between the two groups.

We are working with scientists from the **Patuxent Wildlife Research Center** of the US Geological Survey. Through a project funded by the NRF's Blue Skies programme, we are working with Jim Nichols on analysing bird atlas data using occupancy models.

We have an ongoing collaboration with the **Centre d'Ecologie Fonctionelle et Evolutive** at the CNRS Montpellier.

We have an ongoing collaboration with Colin Beale at the **University of York** on analysing spatial biodiversity data. Colin visited SEEC in December 2016 and presented a seminar on his research.

6. Conferences

6.1 Presentations

1. Altwegg, R. Bird Migration Phenology. Workshop "Seasonal Dynamics". 29 August 2016, University of Cape Town, South Africa.
2. Altwegg, R, Péron, G., Broms, K., Bled, F., and Nichols, J.D. Occupancy models for species range dynamics. 58th Annual Conference of the South African Statistical Association. 28 November - 2 December 2016, Cape Town, South Africa.
3. Altwegg, R, Péron, G., Broms, K., Bled, F. and Nichols, J.D. Range dynamics. International Statistical Ecology Conference. 28 June - 1 July 2016, Seattle, USA.
4. Distiller, G. & Borchers, D. The benefits of using a continuous-time framework for Spatial Capture-Recapture (SCR) models. 58th Annual Conference of the South African Statistical Association. 28 November - 2 December 2016, Cape Town, South Africa.
5. Distiller, G. & Borchers, D. Using continuous-time spatial capture-recapture (SCR) models to make inference about animal activity. International Statistical Ecology Conference. 28 June - 1 July 2016 Seattle, USA.
6. Dlamini, G. & Durbach, I. Individual identification of animals using acoustics. 58th Annual Conference of the South African Statistical Association, 28 November - 2 December 2016, Cape Town, South Africa.
7. Durbach, I. Classification of ecological images and audio using machine learning. 26 October 2016, University of St Andrews, Scotland.
8. Durbach, I., Wolff-Piggott, T., Hampton, S., Moloney, C., & van der Lingen, C. Differentiating fish stocks using image classification. 58th Annual Conference of the South African Statistical Association. 28 November - 2 December 2016, Cape Town, South Africa.
9. Elwen, S., McGovern, B, Tregenza, N. & Gridley, T. (2016). Impacts of acoustic identity pinger tags on bottlenose dolphins? Oral Presentation. Effects of Noise on Aquatic Life Conference, 10-16 July 2016, Dublin, Ireland.
10. Photopoulou, T. & Leos-Barajas, V.. Using hidden Markov models for the analysis of animal acceleration data. 58th Annual Conference of the South African Statistical Association. 28

November - 2 December 2016, Cape Town, South Africa

11. Photopoulou, T., Leos-Barajas, V., Langrock, R., Murgatroyd, M., Underhill, L., Amar, A., Bouten, W. and Altwegg, R. Hidden Markov models for acceleration and three-dimensional movement data in a soaring raptor. International Statistical Ecology Conference. 28 June - 1 July 2016, Seattle, USA.

6.2 Posters

1. Francois Becker at 58th Annual Conference of the South African Statistical Association
2. Qubo Dube at 58th Annual Conference of the South African Statistical Association
3. Tess Gridley at Effects of Noise on Aquatic Life Conference, Dublin, Ireland

7. Publication list 2016

[1] AIELLO-LAMMENS, M. E., SLINGSBY, J. A., MEROW, C., MOLLMANN, H. K., EUSTON-BROWN, D., JONES, C. S., AND SILANDER, J. A. 2016. Processes of community assembly in an environmentally heterogeneous, high biodiversity region. *Ecography* p. Early view.

[2] BEST, P. B. AND PHOTOPOULOU, T. 2016. Identifying the "demon whale-biter": Patterns of scarring on large whales attributed to a cookie-cutter shark *Isistius* sp. *PloS one* 11:e0152643.

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