THE UNIVERSITY of ADELAIDE

Environment Institute

2014 Annual Report

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Contents

02 2014 at a glance

03 Highlights

04 Aligning with South Australia's economic priorities

06 Overviews

08 Leveraging new technologies for cost effective environmental research

10 Maintaining the safety and quality of our water

12 Laureate Fellow, Professor Alan Cooper, ancient DNA and human evolution

14 Researching the past of our microbes to understand more about health and disease today

16 Sustaining viable landscapes

18 South Australian fossils give an exceptional view of past life

20 Safeguarding our marine environment

22 Trapdoor spiders provide key to rapid species identification

24 Managing human-related impacts on biodiverity

26 Institute engagement

27 Environment Institute activities

28 Awards and achievements

30 Board members

31 Our leading members

32 Publications

Environment Institute

2014 Annual Report

Vision

The Environment Institute exists to deliver outstanding research across environmental sciences. To enable this, it brings together leading water and climate scientists and researchers in fields including biodiversity, marine biology, landscapes and genetics.

By developing strong international collaboration and external engagement we can address complex future environmental problems and export innovation to the world.

Connecting knowledge to lead change

Our environmental specialists work together on projects to deliver relevant, innovative and actionable research outcomes in areas of importance to the Australian community including:

- water
- biodiversity
- conservation
- landscape transformation
- oceans and marine biology
- climate change, resilience and adaptation
- genetics, ancient DNA and DNA barcoding

The Environment Institute is affiliated with 8 main programs and centres:

- The Australian Centre for Ancient DNA (ACAD)
- Australian Centre for Evolutionary Biology and Biodiversity (ACEBB)
- Conservation Science and Technology Program (CST)
- Global Ecology Lab (GEL)
- Landscape Futures Program (LFP)
- Marine Biology Program (MBP)
- Sprigg Geobiology Centre (SGC)
- Water Research Centre (WRC)

2014 at a glance

Researchers

25 Leading researchers
389 Total research members

ARC Grant success

1 Australian Laureate Fellowship
3 Future Fellowships
5 Discovery Projects
3 Linkage Projects
2 Discovery Early Career Researcher Awards (DECRA)

Grant income

Category 1	$7,823,714
Category 2	$3,622,976
Category 3	$3,749,544
Category 4	$464,172
Total grant income for 2014	**$15,660,406**

Publications

Our core group of 25 research leaders have produced the following publications in 2014:

166 Journal articles
- **3** Science
- **3** Nature
- **2** Nature Climate Change
- **1** Nature Communications
- **2** Proceedings of the National Academy of Sciences

528 Citations
2 Books
14 Book Chapters
5 Conference Papers

Highlights

The Environment Institute continues to develop strong international collaboration and external engagement to address environmental problems and export innovation to the world.

> **Professor Alan Cooper,** Environment Institute Research Leader and Director of the Australian Centre for Ancient DNA was awarded a prestigious Australian Laureate Fellowship.

> Continued delivery of high impact research evidenced by three publications in both Nature and Science, and two each for Nature Climate Change and Proceedings Of The National Academy Of Sciences.

> Environment Institute research on the evolution of birds from the T-rex in collaboration with the South Australian Museum was named as one of Science magazine's Top 10 breakthroughs of 2014.

> **2014 Future Fellow Dr Lee Arnold** was part of an international team that uncovered new clues to human evolution from the Sima de los Huesos (the pit of bones) in Spain, an archaeological site with the most complete record of human fossils.

> Approval of the establishment of an Unmanned Research Aircraft Facility (URAF) under the directorship of **Associate Professor Lian Pin Koh.** This innovative technology will facilitate research to address biological conservation and land management problems that have traditionally been difficult to implement.

> Success for Environment Institute Members at the South Australian Young Achiever Awards, the SA Science Excellence Awards and the Royal Society of South Australia.

> Chair of the Environment Institute Advisory Board, **Steve Morton** was awarded a Doctor of the University in recognition of his outstanding achievements relating to environmental and natural resource management.

> Three University Medals awarded to Environment Institute members for outstanding PhD Theses. Two of the four Science University Research Medallists from 2014 were from the Marine Biology Group.

Aligning with South Australia's economic priorities

Late in 2014 the South Australian Premier released the State's Top 10 Economic Priorities.

The Environment Institute is already engaged in several of these and will work to increase this engagement into the future. We can demonstrate a strong engagement in:

Unlocking the full potential of South Australia's resources, energy and renewable assets

We have done this via the work of several of our members, in areas as diverse as coal seam gas, the potential of nuclear energy, the impact of increased resource extraction on the Spencer Gulf and the impact of the removal of groundwater on the largely novel Australian stygofauna. The Environment Institute has a strong positive role to play in assisting our State in this priority.

Premium food and wine produced in our clean environment and exported to the world

The marine investigations as part of the Spencer Gulf Ecosystem Development Initiative provides industry with credible evidence based development options to maintain the health of the Gulf and safeguard the quality of seafood exports.

The Knowledge State - attracting a diverse student body and commercialising our research

The world class research carried out by staff within the Environment Institute is a strong attractor of international students and staff to Adelaide, to work in both the long and short term on cutting edge research.

South Australia - a growing destination choice for international and domestic travellers

Much of our research is focused on areas of great interest to the tourism market. For example, we work very closely with the South Australian Museum on the world famous Ediacaran fossil site and the Kangaroo Island Cambrian fossil site. We undertake critical research in marine environments, including ground-breaking research on the Spencer Gulf cuttlefish population and we work to retain clean and healthy marine, freshwater and terrestrial ecosystems.

Growth through innovation

The Environment Institute works with Adelaide Research and Innovation (ARI) to commercialise research and help give Australian business an edge. Research and commercialisation partners are working with governments worldwide to develop DNA tools to support new legislation.

Promoting South Australia's international connections and engagement

The Environment Institute is at the forefront of international connections, both in research partnerships and in research student training. Our staff partner into dozens of countries internationally and they are regular international visitors, as well as hosts to some of the great international scientists of our time.

Overviews

Deputy Vice-Chancellor and Vice-President (Research)

In June 2013 the Australian Government announced a new set of strategic research priorities to drive investment in areas of immediate and critical importance to Australia and its place in the world. In 2014 the Environment Institute continues to produce outcomes in line with these priorities, in areas including living in a changing environment, sound management of our landscape, the provision of abundant clean water and the promotion of population health and wellbeing.

I was delighted to see one of the Institute's key researchers, Professor Alan Cooper, awarded a 2014 ARC Australian Laureate Fellowship. This funding is enabling a new project to use ancient DNA to construct the genetic history of indigenous Australia, and the impacts of colonisation on indigenous people around the world. The project is of national and global importance and the prestigious award cements the international reputations of both Professor Cooper and the University as a world leader in ancient DNA research.

In addition to the Laureate Fellowship, the Environment Institute represented the University exceptionally well in the 2014 Australian Research Council funding rounds, with the award of three new Future Fellowships, five Discovery Grants, three Linkage Projects and two Discovery Early Career Researcher Awards. The Institute continues to support the University's Beacon of Enlightenment strategic goals on multiple levels. There is no doubt that the continued delivery of high-impact research, the establishment of collaborative projects and the ability to attract high quality researchers from around the world, contributes immensely to the University's international standing and reputation for world-class research.

Professor Mike Brooks
Deputy Vice Chancellor & Vice-President (Research)

Advisory Board Chair

I am pleased once more to commend to you this Annual Report from the Environment Institute, with its exciting record of leading-edge research, innovation and collaboration.

The Advisory Board of the Environment Institute continued to meet regularly throughout 2014. The objective of the Advisory Board is to stimulate and encourage the researchers of the Institute by giving them perspectives from the world outside academia. Board members are most excited by research efforts aimed at helping solve the complex environmental issues that confront us as a society, particularly through collective and collaborative approaches. As it happens, board members end up learning more than they impart because of the quality, excellence and breadth of the Institute's researchers. The board feels privileged to be associated with such fine scientists.

The Environment Institute continues to shine as a centre for research excellence. Highlights demonstrating this performance for the year include outstanding results from Australian Research Council funding, especially the Laureate Fellowship awarded to Professor Alan Cooper; continued high-impact publications in *Nature* and *Science*; and the establishment of an Unmanned Research Aircraft Facility under the directorship of Dr Lian Pin Koh. These research achievements clearly demonstrate the growth in academic standing of the Environment Institute.

The advisory board believes that the Environment Institute adds lustre to the University's reputation as a leader in environmental science in Australia. Through its national and international collaborations, plus its efforts in external engagement, the Environment Institute is a noteworthy contributor to the resolution of the environmental challenges facing South Australia, our nation, and the world.

Dr Steve Morton
Chair, Environment Institute Advisory Board

Director

It has been a highly successful year for the Environment Institute. The 2014 Australian Laureate awarded to Professor Alan Cooper is the pinnacle of a multitude of success that spans the entire Institute. Our members continue to deliver excellent research outcomes that support both our State's innovation agenda and the national research priorities. The continued delivery of high impact research is evidenced by three publications in both *Nature* and *Science* in 2014.

During 2014, our research leaders have continued to drive partnerships with government and industry. Innovations such as the establishment of an Unmanned Research Aircraft Facility (URAF) under the direction of Associate Professor Lian Pin Koh will provide a platform for fruitful research partnerships with government and industry. This new technology will facilitate research to address biological conservation and land management problems that have traditionally been difficult to implement.

Increasing international engagement continues to be a priority for the Institute. Our researchers are working alongside world experts at some of the world's premier research resources, such as the Sima de los Huesos (the pit of bones) in Spain, an archaeological site with the most complete record of human fossils. We contribute to the international dialogue by reporting research findings to agencies such as the United Nations and the European Union. Through these endeavours, the Institute continues to attract high quality researchers from around the world, those who are leaders in their fields, as well as excellent research students who are set to become the next generation of research leaders.

Projects such as the Spencer Gulf Ecosystem Development Initiative, exploration of the Kangaroo Island Cambrian fossil site, and the monitoring of carbon uptake and water use at the TERN OzFlux site in Calperum are examples of researchers harnessing the offerings of the State and translating their research into increased productivity for our region.

We have experienced a high level of success with the 2014 ARC funding applications. In addition to the prestigious Laureate Award, we have been awarded three new Future Fellowships, five Discovery Grants, three Linkage Projects and two Discovery Early Career Researcher Awards, further enhancing the potential of the Institute.

The research outcomes delivered by this talented group of people will not only continue to build the international reputation of the University as a world-class institution, but will provide invaluable contributions to some of the great challenges of our time, both locally and globally.

Professor Bob Hill
Director, Environment Institute

Leveraging new technologies for cost effective environmental research

An ultra high resolution orthomosaic of a section of the Arid Recovery Reserve produced from drone images.

> Given the rapid rates of environmental transformation we face today, in an increasingly challenging research funding climate, low-cost civilian drones present promising possibilities.
>
> Associate Professor Lian Pin Koh

Given the rapid rates of environmental transformation we face today, high quality ecological data are needed now more than ever to build the evidence base for informing land use decisions and conservation strategies. Unfortunately, the urgency of this requirement is starkly juxtaposed with an increasingly challenging research funding climate. Low-cost civilian drones present promising possibilities.

The civilian use of unmanned aircraft (or drones) is rapidly gaining popularity and acceptance worldwide. A recent market survey reports that by 2025, the economic impact of the civilian drone market will exceed USD$80 billion in the United States alone, resulting in the creation of more than 100,000 new jobs. The rapid growth of the civilian drone sector creates enormous potential for stimulating Australia's economy as well. In the two years leading to 2014, the number of drone-related Australian companies accredited by the Civil Aviation Safety Authority (CASA) increased 13-fold, from 15 to almost 200.

Drone technology presents excellent cost-saving opportunities in field-based applications such as the detection, monitoring and mapping of wildlife, their habitats and the wider landscape. These applications are highly relevant to natural resource management goals including species conservation, habitat protection and restoration, pest species eradication and watershed management. It also creates new avenues and possibilities for research by enabling the collection of data of much higher spatial, spectral and temporal resolution than conventional approaches.

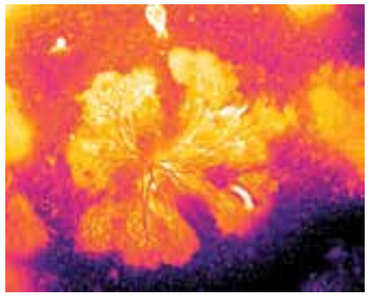
Environment Institute leader Associate Professor Lian Pin Koh is a pioneer in the development and use of these so-called 'conservation drones'. In 2012, he and UK-based primatologist Professor Serge Wich co-founded non-profit ConservationDrones.org, to bring this technology to conservation workers around the world. Since then Associate Professor Koh has partnered with conservation and research organisations from more than a dozen countries including the Smithsonian Tropical Research Institute, World Wide Fund for Nature, the Jane Goodall Institute, Wildlife Conservation Society, Conservation International, Greenpeace, the Max Plank Institute. He also spoke on conservation drones at the 2012 WWF Fuller Symposium in Washington DC, the 2013 TEDGlobal event in Edinburgh, and the 2015 Clinton Global Initiative University in Miami, Florida.

With the support of the Office of the DVC & VP (R), Associate Professor Koh recently established the University of Adelaide's Unmanned Research Aircraft Facility (URAF) as an extension of his research program within the Environment Institute. The URAF currently has six staff members holding Controller Certificates awarded by CASA. It is being accredited for an Operator Certificate for full compliance with CASA guidelines and regulations, and is also in the process of seeking accreditation to provide drone training to staff and students.

Capabilities of the URAF include:

- **Asset Management:** Inspection of Fence Lines, Water and Gas Pipelines, Water Towers, and Cattle Watering Points
- **Precision Agriculture:** Measurement and Analysis of Crop Vigour in High Temporal, Spatial and Spectral Resolution; Livestock Location for Mustering; Integrated Pest Management
- **Wildlife Management:** Thermal Imaging and Detection of Wildlife; Radio Tracking of Collared Animals; Population Estimation of Wildlife
- **Habitat Management:** Mapping and Monitoring of Invasive Plant Species; Mapping of Fire and Burn Sites; Detection and Mapping of Mosquito Breeding Sites
- **Archaeological Surveys:** Scouting and Mapping of Sites of Historical and/or Cultural Significance; 3D Reconstruction of Archaeological Sites

The overarching mission of the URAF is to provide the organisational infrastructure, as well as the technical and legislative knowledge base concerning the use of drones for a wide range of environmental and agricultural applications. It also serves as a coalescing node for fostering partnerships and interactions related to drone applications between students, researchers, and natural resource managers in South Australia.

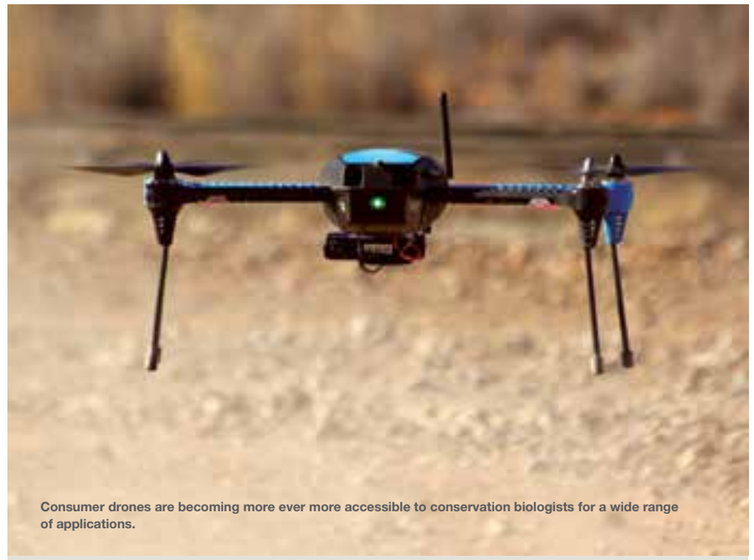


Thermal imaging of a warren of the burrowing bettong.

The URAF has been collaborating with industry partners including:

- SA Department of Environment Water and Natural Resources (DEWNR)
- SA Water Corporation (SA Water)
- Commonwealth Scientific and Industrial Research Organisation (CSIRO)
- Defence Science and Technology Organisation (DSTO)
- Arid Recovery Reserve
- Primary Industries and Regions SA (PIRSA)

For more information about the facility, please visit www.adelaide.edu.au/environment/uraf/



Consumer drones are becoming more ever more accessible to conservation biologists for a wide range of applications.

Drones to monitor SA's environment, water and natural resources

The Department of Environment, Water and Natural Resources (DEWNR) is exploring the use of drone technology for conservation work, particularly in the more remote regions of SA, such as the Natural Resources South Australian Arid Lands region. URAF is collaborating with DEWNR on four projects:

1. Population estimation of colony nesting birds
2. Population estimation of the yellow-footed rock-wallaby and other mammals in hilly terrain
3. Determining survival of released animals
4. Assessing fire severity and estimation of fuel load after prescribed burns.

DEWNR recognises the great potential for this technology to assist in the delivery of projects aimed at the conservation of native fauna species of significance, and the monitoring of natural habitats and fire events.

Maintaining the safety and quality of our water

Access to clean and safe drinking water is something the developed world takes for granted. There is an expectation that every time we turn on the tap there will be a flow of cool, clear potable water. This is not the reality in many parts of the world and a staggering 1 billion people still do not have access to potable water or improved sanitation.

The report of the Open Working Group of the United Nations General Assembly on Sustainable Development Goals, submitted to the Assembly in August 2014, contained 17 goals with 169 targets covering a broad range of sustainable development issues. Associate Professor Justin Brookes was asked to write an article on the United Nation's Sustainable Development Goal 6: Ensure availability and sustainable management of water and sanitation for all.

In the report[1], he outlined four principles for achieving this goal:

1) Separate wastewater from drinking water;
2) Treat drinking water to remove chemical and biological contaminants;
3) Protect and restore freshwater ecosystems; and
4) Guarantee water access and water rights.

The developed world is a long way down the track to achieving these goals. However, there are several water quality issues that continue to plague water utilities and water quality managers. Of particular concern are the cyanobacteria, notorious for forming unsightly scums, producing highly toxic compounds and compounds which taint the taste and odour of water.

The Water Research Centre is active in understanding the physiological traits of the cyanobacteria that enable them to outcompete other algae in stratified lakes, identifying the genes responsible for taste and odour production and determining how the cyanobacteria will respond to a changing climate.

Cyanobacteria have a range of traits that have enabled them to succeed for 3.5 billion years and exploit every habitat on earth. Freshwater cyanobacteria have been particularly successful and have flourished with anthropogenic changes to hydrology and nutrient loading. It is of concern that many modelling studies have predicted that the frequency and intensity of cyanobacterial blooms is likely to increase further with climate change as these organisms grow well in warm temperatures.

Human society has committed to an increase in temperature by our inability to control greenhouse gas emissions. Nutrient control therefore remains the most sustainable tool available to mitigate the predicted increase in cyanobacteria.

However, to manage cyanobacterial growth a deeper understanding is needed on the level of nutrient reduction necessary to counteract the effects of warming and how nutrients interact with indirect effects of temperature as stratification. A meta-analysis[2], Bayesian network modelling of 20 lakes distributed around the globe[3], statistical modelling of the US EPA 1000 lake dataset[4] and process base hydrodynamic-biogeochemical modelling of an oligotrophic and a eutrophic lake all suggest that a reduction in nutrients can offset some of the impacts of climate change on the world's lakes. Nutrient control can be implemented at the catchment scale to build resilience in lake ecosystems to the inevitable increase in temperature.

The global water challenges are great: we need to ensure potable water supply and service irrigation industries to grow food; we need to improve the plight of the billion people without access to clean drinking water; we need to adapt to climate change and the new risks that this presents[5] and we need to ensure water for the environment.

Common to all these challenges is a need to translate the science into management, policy and technology. The Water Research Centre's partnerships with industry enables rapid uptake of the science and adoption into management. This science translation is core to our activities and allows us to blend fundamental and applied science, boosting the impact of our work to influence both local and global water quality improvement.

1 Brookes J.D. and Carey C.C (2015) Rising to the challenge: enabling access to clean and safe water globally. *UN Chronicles Vol LI*, No. 4

2 *Science*, 2011, 6052 (334), 46-47

3 *Ecological Applications*, 2015, 25 (1), 186-199

4 *Limnology and Oceanography*, 2014, 59 (1), 99-114

5 *Environ. Sci. Technol.*, 2014, 48 (4), 2099–2101

> "Human society has committed to an increase in temperature by our inability to control greenhouse gas emissions. Nutrient control of our drinking water therefore remains the most sustainable tool available to mitigate the predicted increase in cyanobacteria."
>
> **Associate Professor Justin Brookes**

Laureate Fellow, Professor Alan Cooper, ancient DNA and human evolution

> "The Australian Centre for Ancient DNA (ACAD) undertakes research and development of advanced ancient DNA approaches for evolutionary, environmental and conservation applications."
>
> **Professor Alan Cooper**

In 2014, Professor Alan Cooper was awarded several ARC grants, most notably a prestigious $2.8M ARC Laureate Fellowship. In addition to his position, the five year Fellowship provides project support and funding for two postdocs and two PhD students.

The Laureate project focuses on understanding the interaction between climate and paleoenvironments, human evolutionary history and the evolution of our microbiome (the bacteria we carry). It will use combined signals of bacterial, genomic and climate data to reconstruct the impacts of migrations, changes in diet, environment, and health in different parts of the world. A major outcome will be a major program studying the genetic history of indigenous Australia, and a detailed understanding of the impacts of colonisation on indigenous people on a global scale.

Over the past three years ACAD has invested heavily to build genomics and bioinformatics capacity, as this area has become the critical bottleneck in any area of research involving DNA. The timing of the Laureate was critical in allowing this strategic development to continue. Key purchases include a second computing cluster for the group, making ACAD the largest single group computing facility in South Australia.

In 2014, the bioinformatics team consisted of three postdocs and three PhD students, and is recognised across the University as an important strategic area of research excellence. ACAD's strategic view is to continue to prioritise the development and integration of bioinformatics and genomics with a wide range of other areas of biology - from human evolution, forensics, health and microbiology, to climate change, paleontology, paleoecology and macroevolution.

Other major ARC funding in 2014 included a Linkage Grant with the South Australian Museum for a landmark study on Indigenous Heritage, using historic hair samples collected by anthropological expeditions between the 1930s and 1960s. This project uses cutting-edge science, detailed archival research, and a comprehensive family outreach and reporting program to develop the first genetic map of Aboriginal Australia. It is designed to work in partnership with Aboriginal communities and individuals to reconstruct personal, family and community history.

The data will allow reconstruction of migration, trading and communication patterns, and investigate the origins of Aboriginal Language Diversity. It is anticipated that both the new knowledge and the focus on Aboriginal Heritage will assist Australia's reconciliation process, and provide powerful material for school education programs.

Further ARC funding in 2014 included a three year Discovery Project on Bovid paleogenomics, aimed at developing Ice Age Steppe Bison of Beringia into a model organism for studying the impacts of climate change, speciation processes, hybridisation and extinction.

Professor Cooper published 29 papers in 2014, including two in Nature and one in Science. Notable results include the first ancient DNA from extinct Australian megafauna (a sthenurine kangaroo and Protemnodon, both from NW Tasmania), a complete phylogeny of marsupials, and the three-part evolutionary history of the modern European genome.

2014 saw two main field expeditions. The first was to the former gold rush city of Dawson in the Yukon, Canada to collect deep frozen animal and plant remains directly from the permafrost. The material is exposed by miners using high-pressure water to accelerate the natural thawing of the permafrost, and includes thousands of bones of large mammals that grazed the steppes of the Berigian region during the late Pleistocene (10 to 200 thousand years ago). Samples of interest were bison, wolves, horses, and plants, and this material is key to an existing ARC Discovery Grant contrasting plant and animal genomic adaptive strategies during periods of pronounced climate change.

The second expedition was to Natural Trap Cave in Wyoming, a 100ft pitfall trap on a ridge high above the Big Horn Canyon Reservoir. The cave is home to a unique collection of Ice Age mammal remains, from animals that have fallen in over the past 100 000 years including a large number of rare carnivores such as the American cheetah and lion, and other species such as camels, bison, mountain sheep and many different horses. The only previous excavation in the cave was in the 1970s, and Professor Cooper is leading a three year NSF funded excavation to collect DNA containing material. Due to his extensive experience in cave exploration, he is also in charge of cave safety and vertical rope work, which is a challenge when dealing with a team of novice US paleontologists.

Ancient DNA and entire genomes of these species will be contrasted between the Yukon and Natural Trap Cave, as these locations were separated by the massive ice sheets covering NW Canada during the Ice Ages. The genetic information will reveal how the species adapted to climate change, speciated, and went extinct during the colonisation of the New World, and how these processes differed in Beringia and the lower 48 States.

Research suggests all modern Europeans have hunter-gatherer and early farmer DNA

Genetic history of Europeans uncovered by 7000 year old German farmer

Researchers Professor Alan Cooper and Dr Wolfgang Haak along with an international team of experts have sequenced the genomes of a ~7,000-year-old farmer from Germany and eight ~8,000-year-old hunter-gatherers from Luxembourg and Sweden.

Upon analysis of the genomes, researchers found that most present-day Europeans derive from at least three highly ancient populations:

- West European hunter-gatherers,
- Ancient north Eurasians (related to Upper Palaeolithic Siberians), and
- Early European farmers of mainly Near Eastern origin.

"Recent genetic studies we did at the University of Adelaide on ancient hunter-gatherers and early farmer remains suggested a massive expansion of people into Europe coinciding with the spread of farming. However, the relative proportions and distributions of the genetic components contributing to modern Europeans remained unclear. This study has added significantly to our knowledge of the genetic make-up of our European ancestors."

They compared the ancient humans to present-day people, looking at the genetics of about 2,400 individuals from almost 200 diverse worldwide contemporary populations.

"The surprising finding was that present-day Europeans trace their ancestry back to three and not just two ancestral groups as previously thought," says ACAD Director and Australian Laureate Fellow Professor Alan Cooper who, together with Dr Haak, is co-author on the study.

The third ancestral group is a mysterious population that spanned North Eurasia and genetically connects Europeans and Native Americans.

Contrary to some previous reconstructions that show Mesolithic people with fair skin, and farmers depicted with dark skin, these findings show the opposite.

This research was published in *Nature* (2014) *513*, 409-413.

Researching the past of our microbes to understand more about health and disease today

What does it mean to be human when 370 trillion microbial cells, ten times the number of human cells, live on the body? This diverse ecosystem of bacteria, fungi and viruses, otherwise referred to as our microbiota has a multitude of complex interactions with the human body, aiding in digestion, supporting the immune system, protecting us from infectious disease, and contributing to our behaviour and well-being.

However, the microbiota has also been recently linked to numerous human diseases, including obesity, diabetes, heart disease and depression. While these are serious health threats, the microbiota are absolutely required for daily bodily functions. Microbiota can also rapidly adapt to dietary and environmental changes, raising important questions about whether or not the bacterial communities we see today are the same as our ancestors', and, if not, what this means for health and disease.

Together with other researchers at the Australian Centre for Ancient DNA (ACAD), Dr Laura Weyrich is examining just these questions, taking a closer look at how the microbial communities have evolved, adapted, and changed through time, along with their human hosts. At ACAD, they are taking a closer look at the evolutionary history of these bacteria, fungi, and viruses.

In 2013, researchers from ACAD described how the bacteria of the human body were impacted during the cultural revolutions in ancient Europe. Drastic alterations of the bacterial species that inhabited the human body first occurred during the Neolithic Revolution (~7,500 years ago), when humans moved away from hunting and gathering, and adopted farming. Another marked shift occurred during the Industrial Revolution (~150 years ago), when large-scale food processing changes occurred.

These microbial changes associated with these revolutions are directly linked to significant changes in oral health, and it is likely that large dietary changes, especially increased dietary carbohydrates and sugar in-take, are the reason for these large-scale microbial changes.

However, these two revolutions did not happen simultaneously worldwide, and were both highly dynamic, while other places did not experience them at all. Around the world, differing plants were cultivated by numerous cultures (e.g. Native Americans in the United States raised corn), while other indigenous groups never adopted agricultural subsistence strategies.

Today, remaining hunter-gatherer societies around the world (Africa, Amazon Basin, and Venezuela) have very different microbiota than Europeans. In fact, microbiota from individuals living in industrialised countries contains less diversity and lack key species that play critical roles in disease, such as obesity and asthma.

Expanding on research published in *Nature Genetics* in 2013[1], our researchers are examining how the distinct histories of different human populations around the world contribute to the microbiota they harbour today, and how these differences may affect their health.

> "Microbiota from individuals living in industrialised countries contains less diversity and lack key species that play critical roles in disease, such as obesity and asthma."
>
> **Dr Laura Weyrich**

Bacteria preserved in ancient, calcified dental plaque (calculus) on human remains allow the researchers to go back in time and examine the bacteria of ancient individuals. Using the preserved bacterial DNA in over 700 different calculus specimens collected globally, ranging from 50,000 years old to the present, they are examining the diversity of the oral microbiota across whole populations, both in ancient times and today.

With the help of universities and museums on six continents, they are exploring microbial diversity in humans as they spread from Africa nearly 60,000 years ago, moved through different environments, ate diverse food sources, and practised different cultural rituals to eventually colonise nearly every continent.

They are also investigating how European globalisation and urbanisation over the past 300 years has impacted this diversity. By surveying microbial diversity in ancient cultures, it will be better understood how the modern microbiota came to be, the events that shaped it, and how the community present in different cultures today contribute to human health, unlocking what it really means to be human.

Laura Weyrich was awarded an ARC Discovery Early Career Researcher Award in 2014.

1 *Nature Genetics*, 2013, 45 (4), 450-455

Sustaining viable landscapes

> Our data will be used to populate and validate vegetation growth, water use and productivity models and feed into the national and international energy, carbon and water exchange models.
>
> **Professor Wayne Meyer**

Carbon, water, drought and fire – life in the Mallee

Following carbon uptake and water use of Mallee vegetation on Calperum Station near Renmark in South Australia has produced some significant insights into how this perennial system has adapted to the extremes of the Australian environment.

A team lead by Professor Wayne Meyer has installed and operated a TERN OzFlux site on Calperum since August 2010. The site adds to the national network of flux sites that are measuring the major ecosystems of the Australian continent. Using the measures of carbon uptake, water used and energy received contributes to the national effort to improve estimates of continental scale effects on global carbon and water balances and terrestrial energy exchange.

Why Calperum?

An OzFlux site has been established in an extensive area of mallee woodland on Calperum Station adjacent to the Chowilla floodplain of the River Murray near Renmark in South Australia. This 'mallee-type' ecosystem is a function of a unique set of pedologic and geomorphic influences in the alkaline terrain unique to southern Australia. These soil types occupy 24% of Australia's land area. The associated ecosystems are undergoing significant human induced change. Their sustainable management is hampered by a lack of understanding of the interdependence among local habitats, the size and extent of flows of energy, nutrients, carbon and water, and the consequent influences on flora and fauna.

The primary aim of the Chowilla Calperum mallee site is to establish the energy, water and carbon fluxes and stores for this ecosystem. This will be combined with vegetation characterisation, carbon stock assessment and surveyed change in vegetation condition over time in response to destocking and fire regimes. The data will complement existing ecological studies of this ecosystem, be used to populate and validate vegetation growth, water use and productivity models and feed into the national and international energy, carbon and water exchange models.

The science questions being addressed are:

- What are the fundamental energy, carbon, water and nutrient stocks and flows in the semi-arid mallee woodland?
- How are these stocks and flows responding to the management interventions - destocking and fire?
- How is the biota changing in form, frequency and distribution as climate changes?

Drought and then rain

The site was chosen in May 2010 with installation of the 20m flux tower and instruments completed in July. The first measures of incoming and outgoing energy, all the weather variables and fluxes of carbon dioxide and water vapour began in August. The region had been in drought for the previous eight years with average annual rainfall between 2006 and 2009 being only 200mm, at least 50mm short of the long term average. In September 2010 rain began with a couple of daily amounts of 40 and 60mm. This was followed with more rain at the start and end of 2011 with an annual total of 510mm.

With this much rain we expected that the mallee and spinifex would respond quickly with increased growth and leaf area. However we could infer from the measurements of water vapour exchange and hence evapotranspiration that this vegetation is very conservative in its water use, even when there is plenty of water in the soil. It was not until a year later that there was a significant increase in the canopy size of the mallee trees (more leaves). The inference from our on-ground measures was confirmed from satellite information that shows the gradual increase in "greenness" as the trees gradually increase their leaf area.

Mallee vegetation gathering carbon

The open path infra-red gas analyser that is measuring the concentration of CO^2 in the atmosphere is combined with information on vertical wind speed measured with a 3D anemometer, both at 20m above the ground. The data from these instruments is collected at a rate of 10Hz, i.e. ten times a second. Large amounts of data are collected through a data logger that aggregates it, stores it and transmits it via radio and telephone links every six hours to the office in Adelaide.

When the data is processed we can see detailed daily, as well as the seasonal effects. For example, the amount of CO^2 in the atmosphere shows a distinct seasonal trend – around 350 ppm in mid-summer to 400 ppm in winter. The measure of CO^2 that we make is a net value that comes from the uptake of CO^2 by photosynthesising plants balanced by the CO^2 released by respiration of both the plants and the organisms in the soil. To estimate how much CO^2 or carbon is being accumulated by the vegetation we need to make an estimate of the rate of ecosystem respiration. This is usually done from the measures of CO^2 at night when there is no photosynthesis.

Unfortunately at night, conditions are often very still so that there is very little mixing of the gases in the atmosphere and with our instruments at 20m above the ground. This lack of mixing causes uncertainty in the sampling of the CO^2 being generated. One way to overcome this limitation is to measure soil respiration independently. This we are now doing as a PhD project, out of which we hope to develop the relationship between soil water availability, soil temperatures and the respiration rates in different patches of the vegetation.

Our first estimates of the amount of carbon that this ecosystem accumulates shows that there are periods of time during the year when soil water and temperature conditions favour respiration over photosynthetic carbon accumulation. At these times there is no net growth of the plants. However over a whole year carbon is being accumulated. Our estimates show that in the four years of 2010 to 2013 the carbon accumulated was 0.3, 2.2, 7.7 and 2.7 t/ha respectively. The largest accumulation occurred in 2012, a year after the drought breaking rains.

Fire and its aftermath

While we were aware that fire is a feature of this ecosystem, hence its mention in our starting objectives, we envisaged something that would be mostly controlled. In January 2014 there was a significant heat wave period when ten of the first 14 days had maximum temperatures above 36C and up to 46C. Thunderstorm activity on the 12th and 13th preceded the bushfire on the 14th. The fire raced through 50,000 ha and at one stage threatened the outskirts of Renmark. We received the 9am download but not the 3pm one. A phenocam camera on top of the tower showed an eerie orange glow at 1pm. The 2pm image showed smouldering stumps and tree trunks, black ashes on the ground and no unscorched leaves in sight. All tower instruments below 10m and all ground wiring had been destroyed. Very fortunately the data logger and equipment in the steel cabinet at the base of the tower was intact. Three months of equipment and wiring replacement followed – a rapid recovery aided by loaned instruments from the OzFlux network and facilitation by University insurance staff.

Fires such as our site experienced result in very large loss of stored vegetation carbon into the atmosphere. However as we were to learn, fire is a great rejuvenator of the mallee. Within a few weeks, new shoots started appearing from the lignotuber (the "mallee stump") of the mallee trees. New, spikey shoots of spinifex started growing from the areas where the clumps of old spinifex provided the ground fuel for the fire, and surprisingly, mallee and *Myoporum* seedlings started appearing even before there was autumn rain.

A year later and the shoots from the mallee roots are nearly a metre high and clearly indicate the base of each tree. The burnt "trunks" stand as black sentinels for what was there before. Soon, many of these trunks will fall over as the termites hollow out the now dead wood just above the live stumps. The many shooting stems will compete for light, water and nutrients to eventually have three to eight dominant ones become the next trunks for the rejuvenated tree; and so the cycle begins again.

Drones and soil bugs

The amount of carbon dioxide taken up by the vegetation and the amount of water evaporated is strongly determined by the area of leaves. We have been regularly monitoring the canopy of the trees using ground based, upward photographs. When the trees had full canopy it is often hard to tell where one tree ends and another is close by.

However, after the fire and with the stump regrowth the location of each tree stump becomes much more obvious. A drone flight over our 1ha vegetation monitoring site next to the flux tower has given us very detailed information on the spacing and distribution of the trees. The tree centres are slightly less than 3m apart on average and randomly distributed. This means that there are often small clumps of trees and then open spaces in which the spinifex proliferates. These patches operate quite differently in terms of organic matter exchange and hence soil respiration. The leaf and bark debris from the trees seems to provide the carbon for soil borne organisms while the open areas tend to remain free of organic debris and hence have much lower respiration rates. This patchwork of microsites is a feature of these semi-arid ecosystems.

South Australian fossils give an exceptional view of past life

> “Adelaide is the only city in the world that is located within a few hundred kilometres of sites that preserve fossils of organisms that lived around the time of the first record of undisputable animals, more than half a billion years ago.”
>
> **Dr Diego García-Bellido**

Some of the world’s most unique fossil collections gathered from the Flinders Ranges and Kangaroo Island are now housed at the South Australian Museum. Dr Diego García-Bellido chose to come to The Environment Institute at the University of Adelaide from Spain in order to expand the knowledge of this branch of scientific endeavour.

Where do the various animal groups come from and how are they related to each other? This is a question that most people have asked themselves at one time or another. And, as with many other fascinating topics in evolution, we don’t have a complete answer yet. One of the various ways of addressing this issue is through the study of fossils, particularly those around the time of the first record of undisputable animals, more than half a billion years ago.

This appearance took place during what is known as the Cambrian ‘explosion’, a sudden –in geological terms– evolutionary radiation about 540–520 million years ago (Ma) after which we find the first representatives of most phyla, such as arthropods (now represented by crayfish, spiders, butterflies), molluscs (which includes modern-day clams, snails and squids), echinoderms (the ancestors of sea starts and sea urchins) and the earliest chordates (the group to which we humans belong), together with a plethora of many other minor groups.

Adelaide is the only city in the world that is located within a few hundred kilometres of sites that preserve fossils of the organisms immediately before and after this major biodiversification event, which is what captivated Spanish palaeobiologist Dr Diego García-Bellido.

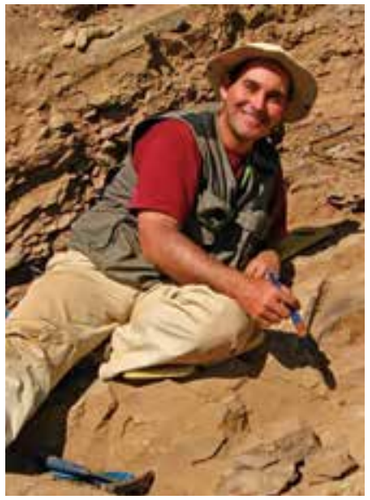
This Adelaidian “perfect frame” for the Cambrian explosion begins in the older rocks, which are found to the north, throughout the Flinders Ranges. Their age is ~555Ma, from the geological period immediately preceding the Cambrian: the Ediacaran. This period of Earth history, recognized all over the world, was officially named after the Ediacaran Hills (about 30km SW of Leigh Creek, in the northern Flinders Ranges) just ten years ago.

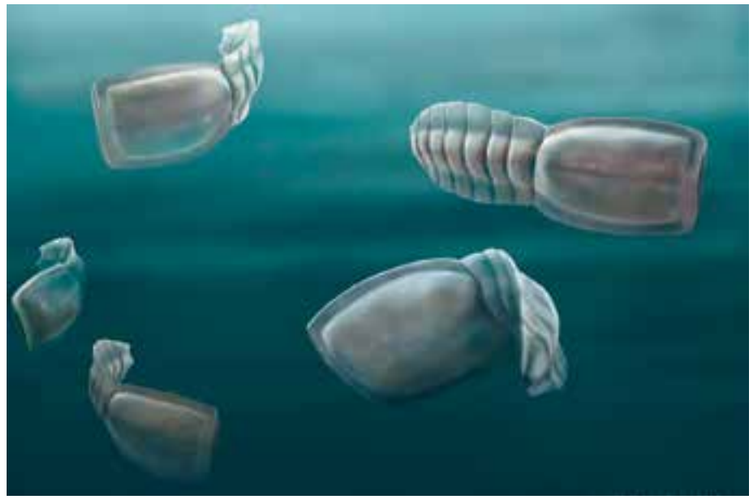
The fossil organisms found there range in size from millimetres to over a metre, and have very diverse morphologies (round, elongated, stalked, with annulations, with fractal branching), but are mostly bi-dimensional and lack any form of hard parts (internal or external skeletons). There are very few examples of movement and feeding, and no evidence at all of predation. The family relationships of most of these organisms are unresolved, and even their assignment to the animal kingdom is still highly debated.

The younger fossil sites are found to the south, along the Fleurieu Peninsula, but especially in the north coast of Kangaroo Island, where the Emu Bay Shale is located. These Cambrian fossils of ~505 Ma are completely different: they are all unequivocal examples of animals, often have shells (like those of clams), spicules or hard, mineralised armours (not unlike some modern crustaceans), and there is clear evidence of predation and other complex behaviour.

The most diverse group is the arthropods (just like today), among them the most abundant are an extinct class known as trilobites, but we also find fossils of sponges, worms, molluscs, echinoderms and early chordates. What is most the striking feature of the Emu Bay Shale is the quality of preservation, where cuticle, muscles, guts (sometimes containing their last meal) and even the most delicate structures (such as eyes) can be found.

Dr García-Bellido and his team are interested in how these different types of organisms lived, how they were related to one another and, more recently, have been looking into the complexity of these earliest multicellular communities and how they changed from the Ediacaran to the Cambrian.





Above: Dr Diego Garcia-Bellido

Above right: An artists impression of the vetulicolians, now believed to be related to humans. (Katrina Kenny)

Right: Emu Bay fossil site, Kangaroo Island, South Australia

Safeguarding our marine environment

> “Incorrect species classification can lead to unsustainable fishing, meaning an isolated cephalopod population may be exploited to extinction.”
>
> Dr Sarah Catalano

Our local environment carries many lessons for global mitigation of climate change and management of increased development and industry activity. Our seafood is exported to the world and our delicate Gulf environment, host to unique marine species, is sensitive to change.

Shipping and the Spencer Gulf Ecosystem

The Spencer Gulf is a rare reverse estuary located where the Indian, Southern and Pacific Oceans meet. An area of unique biodiversity, the Gulf provides a nursery to a significant proportion of South Australia’s fish species. Economic development to this area requires careful management. Considering the impacts of a changing climate is also important.

Professor Bronwyn Gillanders is leading a major marine investigation looking at shipping in the Spencer Gulf that brings together social, economic and biophysical information to understand the Gulf’s environment and assess the growing pressures on it. The Spencer Gulf Ecosystem Development Initiative (SGEDI), focuses on traffic, pest management and potential impacts on the environment. The study aims to enable credible, evidence based assessment of development options that fully consider social and economic benefits while protecting and enhancing the health of the Gulf.

Monitoring shipping is important, as ships from all over the world enter the Gulf each week. There are tankers, ships and carriers from Italy, Liberia, Hong Kong and Panama to name a few. This poses biosecurity risks in terms of introduced species. Professor Gillanders has been involved with studies surrounding the effects of shipping on the giant Australian cuttlefish in the Gulf, and believes that further research and monitoring would help enable sustainable recommendations for proposed new ports, including Port Spencer and the Port Bonython expansions.

Sustainable industry development for Spencer Gulf

> “We want to ensure that the scientific evidence helps inform public opinion and delivers positive outcomes.”
>
> Professor Gillanders

Major industries, BHP Billiton, Santos, Alinta, Arrium Mining, Centrex Metals, Flinders Ports and Nyrstar are working together with the Fisheries Research and Development Corporation, Adelaide University’s Marine Innovation SA collaborators, South Australian Research and Development Institute and Flinders University are partnering in the SGEDI project led by the University’s Environment Institute.

“The Spencer Gulf is a prospering development zone for South Australia but also home to an ecosystem of national significance and great value. Simultaneously managing commercial and environmental interests is like juggling fish - but through this initiative we believe we can drive responsible decision-making for a thriving Gulf region.”

SGEDI’s vision is a thriving Gulf region where progressive development continues alongside a protected and enhanced ecosystem - and community opportunity is optimised.

To date the initiative has developed a knowledge review of the gaps in science relevant to the Gulf’s ecology. It is working towards the framework and science program for a structured decision-making process on future development that takes into account social, economic, cultural and ecological concerns. All this will be placed within an integrated marine management framework.

The project also aims to deliver clearer development approval pathways with potential to reduce costs and time delays.

The secret lives of marine parasites

New research by Dr Sarah Catalano could provide a tool to ensure current fishing practises are sustainable and avoid extinction of local species.

Parasites are everywhere - plants, animals, humans, even parasites themselves, can be host to a whole suite of different parasite species which can infect every organ and surface of the body. Although they are often overlooked, parasites can provide many clues and answers to challenging questions in biology.

With knowledge on how a parasite is transmitted and at which stage of its lifecycle, mechanisms can be set in place to break this transmission, which is especially useful to prevent parasite outbreaks in natural and cultured populations. Parasites can also provide insights into the hosts they infect, including host range, habitat, longevity, diet and social behaviour.

Recent research has explored the use of parasites as biological tags to assess host population structure, as parasites can be more finely subdivided between host populations then revealed using other techniques.

One little-known group of marine parasites are the dicyemid mesozoans. These tiny organisms are found exclusively in the kidneys of benthic cephalopods (squid, octopus and cuttlefish), and while they are simple in appearance – made up of only 8-40 cells without any obvious tissue structure – they do have surprisingly complex lifecycles.

They have two modes of reproduction, asexual and sexual, and exist in two forms. Adults are long and slender whereas embryos can be a clone of the adult only smaller, or have a distinctive circular form. To infect a new host, the circular embryo form of the parasite is released with the host’s urine out into the sea. It then has to find a new squid or cuttlefish or octopus individual that is of the right species within a limited time-frame before it perishes, while also battling environmental conditions such as strong water currents and varying salinity. Somehow this tiny organism – just a few cells in size – manages this complex and highly specific reinfection and the astonishing lifecycle beings again.

While over 100 species of dicyemids had been described worldwide, there was a clear knowledge gap from Australian waters, with no species described from this area. Questions such as their natural level of infection in our waters, faunal composition and genetic framework were all missing.

In order to shed light on this knowledge gap, some exciting new research was initiated. To date, it has formally described ten new dicyemid species from six Australian cephalopods, representing the very first records from our waters. Patterns of infection and faunal composition were explored in comparison to Northern Hemisphere counterparts, and unknowns in the dicyemid lifecycle were investigated.

Surprisingly, they found that the left and right kidneys of a single host individual were infected independently of each other, with one kidney infected by asexual forms and the other by sexual forms, suggesting this mechanism is parasite-controlled not host-mediated.

To combat the lack of genetic framework for this group, the complete mitochondrial COI minicircle molecule was sequenced for ten dicyemid species, allowing the first preliminary phylogeny to be published. Characteristics and the evolutionary consequences of this unusual mitochondrial genome architecture was also investigated.

The use of dicyemid parasites as biological tags to assess cephalopod host population structure was also examined. As these parasites are found in high numbers in the kidneys of benthic cephalopods, and are highly host-species specific, they represented worthy candidates to explore host population structure.

Using a combination of classical taxonomic methods and molecule genetic techniques, it was uncovered that host species could be re-classified with high accuracy to their true biological entity based on dicyemid faunal composition. In addition, different dicyemid species distributions were found at different geographic collection localities for some cephalopod species, suggesting further cryptic population structuring that was not apparent from phylogeographic analysis of the hosts themselves.

This is important as we are asking whether these cephalopods belong to a single group or species, or whether they are significantly different from each other that they warrant placement in two or more groups or species.

If this is overlooked, what may be thought of as a sustainable fishing practise could be wrong, meaning an isolated cephalopod population may be exploited to extinction. Our research can inform cephalopod fisheries management in an effort to ensure cephalopods remain in our marine environment for future generations to come.

This research has not only increased knowledge on our own previously undocumented dicyemid parasite fauna, but also contributed to the overall worldwide body of research on this group by providing a phylogenetic framework, Southern Hemisphere counterpart comparison and a tool for using dicyemids as biological tags to assess host population structure.

Sarah Catalano conducted this research as part of her PhD thesis under the supervision of Professor Bronwyn Gillanders, Professor Steve Donnellan, and Associate Professor Ian Whittington, resulting in the following publications:

International Journal for Parasitology: Parasites and Wildlife, 2014 3 (2): 220–226

Folia Parasitologica, 2014, 61 [4]: 301–310.

Trapdoor spiders provide key to rapid species identification

Idiosoma nigrum, perhaps better known as the Black rugose trapdoor spider, are found only in south-western Australia, They live in burrows up to 32cm deep and can live for over 20 years.

Trapdoor spiders belonging to the family Idiopidae are extremely diverse in Australia and highly endemic at all taxonomic levels, with nine genera, over 100 described species and a large number of undescribed species known from collections.

The family has experienced a massive evolutionary radiation on the continent, especially in temperate and subtropical Western Australia, and due to their longevity (> 20 years), habitat specialisation, poor powers of dispersal and propensity for short-range endemism, many species are of conservation significance.

A Western Australian species, *Idiosoma nigrum*, is currently listed as vulnerable under both Western Australian and Commonwealth conservation legislation. All excavate burrows, and most species in the family build highly camouflaged trapdoors.

This group of spiders is the focus of a large ARC Linkage Project which is examining their evolution and biogeography, and implications for conservation biology and environmental assessment. Professor Andy Austin, Director of the Australian Centre for Evolutionary Biology and Biodiversity (ACEBB) is leading the project, and has spider expert Dr Mike Rix as an Industry Australian Postdoctoral Fellow involved in all aspects of the research.

The industry partners are Rio Tinto, BHP Billiton, Biota Environmental Sciences, Western Australian Museum and the South Australian Museum, with the involvement of the mining and assessment companies being aligned with the conservation significance of these spiders, their relevance to the environmental approvals process, and the need to develop better methods of molecular species identification.

The specific aims of this project are to:

- develop high-throughput molecular methods for the next-generation sequencing of multiple loci.
- test the phylogeny and generic classification of the Idiopidae within Australia.
- reconcile gene trees and species trees for Australian taxa, to investigate the utility of different molecular markers for accurate species delimitation, and infer potential 'hotspots' of idiopid diversity and endemism.

It is the last of these aims that is central to industry involvement in the project, with a core focus on developing better molecular markers for rapid species identification.

The development of next-generation sequencing (NGS) genomic technologies and fieldwork has now been completed. Funding from the Environment Institute (to Mike Rix) has been crucial to the development and testing of an NGS method that allows numerous genes to be sequenced from 96 samples simultaneously.

This method, called parallel tagged amplicon sequencing, will now be used to generate a massive multi-gene dataset for nearly 300 idiopid trapdoor spiders. These data, to be generated prior to the completion of the project at the end of 2015, will form the basis of all subsequent analyses.

The results will provide an unparalleled insight into the phylogeny of Australian trapdoor spiders, the diversity and biogeography of the Australian fauna, and the identification of species in lineages of major conservation significance.

Follow-up funding from the Australian Biological Resources Study has been awarded to APDI Mike Rix, allowing the results of this project to be fully analysed, published and further translated into a rigorous taxonomy for the Australian idiopid spider fauna.

The following publications have been enabled by this ARC Linkage Project:

Invertebrate Systematics, 2014, 28, 375-385.

Biological Reviews, 2014 (in press, doi: 10.1111/brv.12132)

Above: Lichen-encrusted trapdoor of *Euoplos* sp. from Young, NSW.

Right: Live female spider of the Western Australian species, *Idiosoma nigrum*

Managing human-related impacts on biodiversity

Managing human-mediated impacts continues to be a clear focus for conservation biology, but with an increasing acknowledgement that extinction drivers are usually interacting and self-reinforcing. Understanding how biodiversity will respond to future human impacts requires innovative new approaches which explicitly couple ecological and climatic-geophysical processes.

Delivering the predictive tools required to anticipate ecological responses to climate change in the context of other human-driven threatening processes is a central theme of the research being undertaken by Dr Damien Fordham, 2014 ARC Future Fellow. In his current project: "Integrating models with molecular 'logbooks' to better forecast extinction risk from climate change", he uses complex mechanistic models to improve forecasts of how biodiversity will respond to environmental change.

This research includes:

- Balancing model complexity and predictive skill to improve forecasts of species' range movement and persistence in response to global change
- Using the fossil record and genetic data to determine uncertainties in forecasts of species' responses to climate change
- Incorporating evolutionary and demographic processes into phenomenological and mechanistic models
- Accounting for complex species interactions in climate change simulation models
- Using the species area relationship to calculate extinction risk under climate change

Study finds population control is no environmental quick fix

> "Global population has risen so fast over the past century that roughly 14% of all the human beings that have ever existed are still alive today - that's a sobering statistic. This is considered unsustainable for a range of reasons, not least being able to feed everyone as well as the impact on the climate and environment."

Professor Corey Bradshaw

Multi-scenario modelling of world human population used by Professor Corey Bradshaw and Professor Barry Brook has shown that even stringent fertility restrictions or a catastrophic mass mortality would not bring about large enough change this century to solve issues of global sustainability.

Published in the *Proceedings of the National Academy of Sciences of the USA*, the study highlighted that the "virtually locked-in" population growth means the world must focus on policies and technologies to reverse the rising consumption of natural resources and enhance recycling, for more immediate sustainability gains. Fertility reduction efforts, through increased family-planning assistance and education, should still be pursued, as this will lead to hundreds of millions fewer people to feed by mid-century.

"We examined various scenarios for global human population change to the year 2100 by adjusting fertility and mortality rates to determine the plausible range of population sizes at the end of this century. Even a world-wide one-child policy like China's, implemented over the coming century, or catastrophic mortality events like global conflict or a disease pandemic, would still likely result in five to ten billion people by 2100."

The researchers constructed nine different scenarios for continuing population ranging from "business as usual" through various fertility reductions, to highly unlikely broad-scale catastrophes resulting in billions of deaths. Their work revealed that effective family planning and reproduction education worldwide have great potential to constrain the size of the human population and alleviate pressure on resource availability over the longer term.

"The corollary of these findings is that society's efforts towards sustainability would be directed more productively towards reducing our impact as much as possible through technological and social innovation."

This research was published in Proceedings of the National Academy of Sciences of the USA 2014, 111 (46): 16610-16615.

Dingos could bring economic benefit

Research undertaken by Professor Corey Bradshaw, Associate Professor Phill Cassey and Dr Thomas Prowse shows that stopping control measures such as baiting and fencing could increase net profit for cattle graziers.

Research models published in the *Journal of Applied Ecology*, that the profit margin could be improved by as much as $83 000 a year for a 100 000 hectare cattle station.

"Our study challenges the conventional perception of dingoes as an economic pest that must be controlled. By helping dingoes thrive, we expect improved biomass of native pastures through the reduction of kangaroo populations – and improved returns to cattle graziers."

The researchers developed a multi-species model of the food chain and economics of a rangeland cattle enterprise, including simulations of pasture regrowth, grazing pressure and cattle live-weight gain. Trade-offs between livestock density, kangaroo abundance, calf losses and dingo control were examined.

"Dingoes are predators and they do occasionally take out young livestock, but they also eat a lot of kangaroos and, in fact, seem to prefer them.

In a typical cattle station setting in arid Australia, cattle and kangaroos compete for the most limiting resource - grass and other vegetation. With fewer kangaroos around, there is more grass for cattle to eat and more food means bigger and fatter cattle, which leads to more profit for the grazier."

The researchers showed that under normal stocking conditions in outback Australia with unbaited dingoes and controlled kangaroos, pasture biomass increased by 53kg a hectare.

Not only are the graziers' profits higher, but there is less inter-annual variation. Fewer kangaroos reduces the amount of change in grass biomass from one year to the next."

This research was published online in the *Journal of Applied Ecology*, 18 December 2014.

> "Global extinction rates have soared over the past century, due predominantly to the resource demands of a burgeoning human population. Shifting land-use and wildlife exploitation, and elevated rates of competition and predation by invasive organisms have reduced the range and abundance of many species, directly causing severe biodiversity loss at local scales, and indirectly limiting the scope for sufficient ecological and evolutionary adaptation to future environmental change."

Dr Damien Fordham, 2014 ARC Future Fellow

Institute engagement

Environment Institute activities

2014 snapshot

50K unique web page views
25 Media releases
20% increase in Facebook community
10% increase in a well-established (>2000) Twitter community
14 Seminars by visiting researchers
8 Training workshops and conferences

In the news

The Environment Institute continues to receive solid coverage in the media. The Institute and our researchers actively publicise their research to help inform and engage the community on relevant environmental issues, as well as maintain visibility to aid in the formation of new relationships and collaborations with industry and government.

Many of our researchers communicate their research to a broad audience through in-depth interviews on radio stations including ABC 891 Adelaide, ABC Radio National and the University's own Radio Adelaide, appearances on television programs such as the 7:30 report and writing for news sites including the *Conversation* (14 articles) and local Adelaide University magazine *eScience* (nine features).

There were many research breakthroughs that made headlines around the world. Some of the top stories of the year include:

> ***"How small birds evolved from giant meat eating dinosaurs"***

Research lead by Associate Professor Mike Lee and published in the journal *Science*. This discovery was also listed as one of *Science* magazines top ten breakthroughs of 2014.

> ***"Ancient DNA ends Aussie claim to kiwi origins"***

A study published in *Science*, led by Professor Alan Cooper dispelled the long held belief that the extinct elephant bird of Madagascar was closely related to the emu, when in fact, ancient DNA studies now reveal it is closely related to New Zealand's kiwi. The story was picked up by over 600 media outlets, one of Adelaide University's best records.

> ***"Reducing population is no environmental 'quick fix'"***

Professor Corey Bradshaw's research published in the *Proceedings of the National Academy of Sciences of the USA*, sparked worldwide interest following the finding that even a world-wide one-child policy like China's, implemented over the coming century, or a catastrophic mortality event like global conflict or a disease pandemic, would still likely result in five to ten billion people by 2100. The research was reported by news outlets including BBC News, *The Washington Post* and the *Huffington Post*.

> ***"Scientists are live tweeting a major fossil dig in Wyoming"***

There was a social media flurry as a result of Professor Alan Cooper's visit to the Natural Trap Cave in Wyoming, USA. Alan was filmed by fellow Australian Centre for Ancient DNA researchers inside the cave, answering questions about ancient DNA and the fossil site, which is a site containing fossils of extinct megafauna. The video has received over 35 thousand views following being picked up by CNN after being tweeted by The Bureau of Land Management in Wyoming. Samples from the cave have been brought back to Adelaide for analysis.

Events

The Researchers at the Environment Institute continue to communicate their research to a wide audience, to both the public and the broader scientific community including industry, government and other universities.

The Institute strives to maintain engagement with the community through both involvement with and hosting of some fantastic events:

> **WOMADelaide 2014:** Professors Tom Wigley and Peter Ward were invited panellists for the Planet Talks

> **Science in the Pub:** Professor Corey Bradshaw presented *"The bees knees: The importance of pollinators and their recent decline"*.

> **2014 South Australian Climate Adaptation Showcase:** presentation by Bayden Russell.

> **DEWNR NRM Science Conference:** Corey Bradshaw, Barry Brook, Phill Cassey, Sean Connell, Steven Cooper, Graeme Dandy, Bronwyn Gillanders, Andrew Lowe, Wayne Meyer, John Tibby and Michelle Waycott all presented at this two day conference attended by over 500 government, industry and university representatives.

> **The Natural History of Spencer Gulf Book launch:** Professor Bronwyn Gillanders co-edited the book and has also authored a chapter on the giant Australian cuttlefish. The book was officially launched by Minister Brock.

> Professor Richard Fortey delivered a public lecture attended by over 400 people (co-hosted by ACAD)

Seminars

The Institute continues to connect and collaborate with prestigious international and interstate researchers.

In 2014 the Environment Institute hosted the following visiting speakers:

Speaker	Seminar title	Origin	Date
Professor Stephen J Hawkins	100 years of observations from the Marine Biological Association	University of Southampton, UK	20 January
Professor Barbara Minsker	Sustainable and resilient urban stormwater management	University of Illinois, USA	19 March
Dr Jonathan Sanderman	The soil organic matter conundrum: Why do thermodynamically unstable compounds persist in soils?	CSIRO Land and Water, Adelaide, Australia	4 April
Professor John Long	Exceptional fossils and new technologies: revealing the big steps in early vertebrae evolution	Flinders University, Adelaide, Australia	2 May
Dr Nerilie Abram	Warming and ice melt on the Antarctic Peninsula	Australian National University, Canberra, Australia	30 May
Professor Eelco Rohling	Continuous, well dated records of sea level change: new details for the past 500ky, and first extension over 5.3 My	Australian National Museum, Canberra, Australia	27 June
Professor John Pandolfi	Historical perspective in marine ecology and conservation	University of Queensland, Brisbane, Australia	1 August
Dr Kale Sniderman	Pliocene reversal of late neogene aridication: vegetation history of semi-arid Nullarbor Plain based on U-Pb dated speleothem pollen record	University of Melbourne, Australia	29 August
Professor Fangliang He	Modelling species distributions in fragmented landscapes	University of Alberta, Edmonton, Canada	22 October
Dr Franck Courchamp	Interactions between climate change and biological invasions	University Paris XI, France	5 November
Dr Pauline Grierson	Delta-O^{18} fingerprinting to understand past and present hydro climate and ecological water requirement in Western Australia	University of Western Australia, Australia	7 November
Professor Richard Fortey	Survivors: the animals and plants that time has left behind	Senior palaeontologist, Natural History Museum, London, England	28 November
Professor Katherine Freeman	A haystack from a needle: using biomarkers to understand ancient forest structure	Pennsylvania State University, USA	5 December
Dr Melvin Gumal	Burning the midnight oil – conservation of orang-utans, tigers and elephants in Malaysia	Malaysia Program Director, Wildlife Conservation Society, Malaysia	8 December

Conferences & Workshops

In 2014 The Environment Institute supported the following well attended training workshops and conferences:

> GEL Linnaeus Workshop

> GEL Spatial Statistics and Modelling of Species distribution workshop delivered by Fangliang He

> ACAD Computational Macroevolution: analysis and visualisation of complex dynamics on phylogenetic trees workshop

> ACAD Computational Genomics workshop

> ACEBB Advanced workshop in Bayesian Phylogenetics and Dating

> SGC Compound-Specific Isotope Analysis (CSIA) workshop

> SGC 18th Australian Organic Geochemistry Conference

> Early Career Researcher Leadership Development Workshop "Dragons Den", presented by Karilyn Fazio from Impetus

Awards and achievements

Congratulations to Environment Institute members

Doctor of the University (honoris causa)

Dr Steve Morton, Chair of the Environment Institute Advisory Board, received a degree of Doctor of the University (honoris causa) in recognition of his outstanding achievements relating to environmental and natural resource management.

Steve Morton received his Bachelor of Science with Honours and PhD in animal ecology from the University of Melbourne. He then went on to postdoctoral studies at the University of California, Irvine, and the University of Sydney. He joined CSIRO in 1984 at the Alice Springs laboratory and transferred to Canberra, a decade later.

Dr Morton was Chief of CSIRO's Division of Sustainable Ecosystems from 2000 to 2003. In this role he effected the merger of CSIRO Wildlife and Ecology with Tropical Agriculture to create a new Division focused on sustainability science, led expansion of economic and social science expertise in CSIRO, stimulating growth of a cadre of staff from about 20 to 150 today, and re-developed engagement of CSIRO with Aboriginal people, leading to focus on Indigenous R&D in northern laboratories and a formal Organisational Indigenous Engagement Strategy.

From 2003 to 2005 he was Group Executive, CSIRO Environment and Natural Resources, where he led the creation of large-scale National Research Flagship Programs in Water and Oceans across several CSIRO Divisions; and oversaw the merger of two Divisions into CSIRO Marine and Atmospheric Research, the largest such research group in the Southern Hemisphere. From 2005 to 2007 he was Group Executive, CSIRO Sustainable Energy and Environment, where he negotiated combined R&D effort from the Bureau of Meteorology and CSIRO to form the Centre for Australian Weather and Climate Research; led a successful bid for Commonwealth Government funding to a new Climate Adaptation National Research Flagship Program; and led a successful bid for expanded Commonwealth Government funding to the Energy Transformed National Research Flagship Program. From 2008 to 2010, he was Group Executive, CSIRO Manufacturing, Materials and Minerals.

Amongst many other roles, Dr Morton has been a board member for two CRCs; Chair of the Working Group on Natural Systems and Biodiversity, Prime Minister's Science, Engineering and Innovation Council, Canberra; a member of the Wentworth Group of Concerned Scientists; and many other specialist roles in government and industry advisory groups. He chaired the Advisory Committee of the University of Adelaide's Centre for Evolutionary Biology and Biodiversity for ten years from 2001, and since 2011 has been chair of the Advisory Board of the University's Environment Institute.

He has published more than 140 scientific papers, book chapters, books, refereed reports and popular articles. He is currently an Honorary Fellow with CSIRO Ecosystem Sciences at Alice Springs. Dr Morton is one of the country's foremost thinkers on issues facing conservation, land management and ecological sustainability.

Dr Steve Morton

Alison Snel, Communications & Marketing Manager, Flinders Ports presented the Award to Sarah (right)

Sarah Catalano completed her PhD on a poorly understood and little-known group of marine parasites called dicyemid mesozoans, which are found in high numbers on the kidney surface of cephalopods, including squid, octopus and cuttlefish species. Her research has discovered and described ten new parasite species, the very first from Australian waters. Her approach of using parasites as tags for these creatures may guide future conservation efforts to maintain species diversity in our waters, and has earned her numerous awards including a **Dean's Commendation in Doctoral Thesis Excellence**, a **SA Science Excellence Award** for PhD research excellence in life and environmental sciences category, the **Harold Woolhouse Prize** for best PhD thesis produced in the Faculty of Sciences, and a **2014 University of Adelaide Doctoral Research Medal**. Sarah also received the **South Australian Channel 9 Young Achiever Award** in the Flinders Port Holdings Environment category.

Channel 9 Young Achiever Award

Congratulations to Sarah Catalano who received the South Australian Channel 9 Young Achiever Awards Flinders Port Holdings Environment Award. The award recognises those who are dedicated to nurturing and protecting our natural surroundings, and demonstrating real environmental impact on a local, national or world scale.

Laura Falkenberg was runner up for the South Australian Channel 9 Young Achiever Awards Flinders Port Holdings Environment Award. Laura's PhD reshaped how people think about managing climate change. She showed that local management of pollution can substantially reduce the effects of ocean warming and acidification which are not under the control of local managers. Her work was highlighted by the European Union in a communication to their environmental policy makers.

University Doctoral Medal

Congratulations to Sarah Catalano, Owen Burnell, and Simon Divecha who have all been awarded the prestigious 2014 University of Adelaide Doctoral Research Medals. The Doctoral Research Medal Award recognises the highest quality PhD theses examined each year. Two of the four science University Research Medalists from 2014 were from the Marine Biology Group.

Sarah Catalano's PhD included research on the giant Australian cuttlefish and the unknown reasons for their fluctuating population. Sarah completed her PhD under the supervision of Professor Bronwyn Gillanders, Professor Steve Donnellan and Associate Professor Ian Whittington.

Owen Burnell completed work identifying how local and global scale changes in marine systems can shape seagrass habitats. Owen completed his PhD under the supervision of Professor Sean Connell, Dr Bayden Russell and Dr Andrew Irving.

Simon Divecha presented research on the impact of climate change on business strategy, culture and collaboration in two major international companies. Simon is currently working with the Environment Institute as a consultant for the Spencer Gulf Ecosystem and Development Initiative as well as the ARC Discovery Grant funded Aboriginal Hair project led by Professor Alan Cooper.

SA Science Excellence Award

Sarah Catalano has been awarded the SA Science Excellence Award for PhD research excellence in the Life and Environmental Sciences category.

Royal Society of SA Award for best PhD Presentation

Andrew Farrer

Board members

Dr Steve Morton (Chair)
Honorary Fellow,
CSIRO Ecosystems Sciences

Dr Steve Morton is an Honorary Fellow with the CSIRO Sustainable Ecosystems in Alice Springs in the Northern Territory. As well as being chair of the Advisory Board for the Environment Institute, he is also Director of Bush Heritage Australia, a Board Member of Desert Knowledge Australia, Director on the Board of Territory Natural Resource Management and Chair of the Seven Member Lake Eyre Basin Scientific Advisory Panel. He is interested in the ecology of Australian deserts, science of Indigenous advancement, and the use of R&D for natural resource management.

Dr Susannah Eliot
Chief Executive Officer, Australian Science Media Centre

Susannah Eliot has more than 20 years of practical experience in science communication. Susannah is currently CEO of the Australian Science Media Centre, an independent not for profit organisation that works with the news media to highlight the scientific evidence behind the story. Previously appointed to the national Climate Commission and Chair for the Expert Working Group on Science and the Media for the Federal Government. She currently sits on the Federal Government's Science Sector Working Group and the Environment Institute Board.

Mr Carl Binning
Managing Director, Creating Communities

Carl Binning is the Managing Director of Creating Communities. A believer in sustainable development, he provides advice on integrating communities with environmental and economic strategies. Over the last 20 years he has held various senior leadership positions within industry, government and community. He was Vice-President of Health, Safety, Environment and Communities for BHP Billiton's Iron Ore Business and Chief Executive of Community based environment organisation, Greening Australia. Carl has also held roles at CSIRO as Principal Research Economist in Wildlife Ecology, where he focused his research on designing economic incentives and institutions for sustainable natural resource management and developing mechanisms for the conservation of biodiversity outside public nature reserves. He has a profound interest in the integration of economic and social issues with environmental policies.

Ms Pauline Gregg
General Manager (Environment), Telstra

Pauline Gregg is Telstra's General Manager – Environment, and is responsible for their environmental strategy. Pauline has over 20 years experience in environmental sustainability in both the public and private sectors. Pauline is passionate about educating companies on the importance of the environment in their operations. Pauline's interest in the environment has seen her take on an advisory role to the Board of the Environment Institute.

Professor Mike Brooks
Deputy Vice Chancellor and Vice-President (Research), University of Adelaide

Professor Mike Brooks is the Deputy Vice-Chancellor and Vice-President (Research) at the University of Adelaide. He is a leading international researcher in computer vision and image analysis. His work has seen wide commercial use in the security and defence industries and has resulted in international awards. Professor Brooks has published many influential papers in the areas of auto-calibration, structure from motion and video surveillance. He is a Fellow of the Australian Computer Society, a Fellow of the Australian Academy of Technological Sciences and Engineering, Associate Editor of the International Journal of Computer Vision, and serves as a non-executive director on several boards.

Mr Allan Holmes
Allan Holmes has been a career public servant with more than 35 years of service in Victoria and South Australia. He recently left government after 15 years as chief executive of the South Australian Department of Environment, Water and Natural Resources. He has worked in biochemistry, agriculture, environment protection, forestry, park management and nature conservation. He currently chairs Nature Play SA, is a board member of the SA EPA as well as Arid Recovery Inc. and consults intermittently. Allan is an active contributor to public discussion of environmental matters.

Our leading members

Professor Bob Hill, Director
Director, Environment Institute

Professor Bronwyn Gillanders
Deputy Director, Environment Institute
Director, Marine Biology Program
Spencer Gulf Ecosystem Development Initiative Lead Researcher
Australian Research Council Future Fellow

Professor Andy Austin
Director, Australian Centre for Evolutionary Biology and Biodiversity

Associate Professor Jeremy Austin
Deputy Director, Australian Centre for Ancient DNA
Australian Research Council Future Fellow

Professor Corey Bradshaw
Co-Director, Global Ecology Laboratory
Australian Research Council Future Fellow

Professor Barry Brook
Sir Hubert Wilkins Chair of Climate Change
Co-Director, Global Ecology Laboratory
Australian Research Council Future Fellow

Associate Professor Justin Brookes
Director, Water Research Centre

Associate Professor Phill Cassey
Deputy Director, Conservation Science and Technology
Chair of Biosecurity and Invasion Ecology

Professor Sean Connell
Australian Research Council Future Fellow
Marine Biology Program

Professor Alan Cooper
Director, Australian Centre for Ancient DNA
Australian Research Council Future Fellow
Australian Research Council Laureate Fellow

Professor Steve Cooper
Principal Research Scientist of the South Australian Museum Evolutionary Biology Unit
Australian Centre for Evolutionary Biology and Biodiversity

Dr Damien Fordham
Australian Research Council Future Fellow
Global Ecology Laboratory

Dr Diego Garcia-Bellido
Australian Centre for Evolutionary Biology and Biodiversity
Sprigg Geobiology Centre
Australian Research Council Future Fellow

Associate Professor Frank Grutzner
Australian Research Council Future Fellow

Professor Martin Kennedy
Director, Sprigg Geobiology Centre

Associate Professor Lian Pin Koh
Deputy Director, Conservation Science and Technology
Chair of Applied Ecology and Conservation

Associate Professor Mike Lee
SA Museum

Professor Megan Lewis
Associate Dean - Future Students Sciences

Professor Andy Lowe
Director, Conservation Science and Technology
Chair of Plant Conservation Biology

Professor Wayne Meyer
Director, Landscape Futures Program

Associate Professor Ivan Nagelkerken
Australian Research Council Future Fellow
Marine Biology Program

Professor Peter Ward
Sprigg Geobiology Centre

Professor Michelle Waycott
HBS Womersley Chair in Systematic Botany
Chief Botanist of the State Herbarium of South Australia

Professor Tom Wigley
Australian Research Council Discovery Outstanding Researcher Award

Professor Phillip Weinstein
Head of school of Biological Sciences

Publications 2014

The following list comprises The Environment Institute's Top 20 Impact Factor Publications in 2014. 166 journal articles were published by our leading researchers. To view this list, please visit: www.adelaide.edu.au/environment

1. Orlando L, Cooper A. Using ancient DNA to understand evolutionary and ecological processes. ***Annual Review of Ecology, Evolution, and Systematics***; 2014. pp. 573-598.

2. Burivalova Z, Şekercioğlu ÇH, Koh LP. Thresholds of logging intensity to maintain tropical forest biodiversity. ***Current Biology*** 2014, ***24***(16): 1893-1898.

3. Wich SA, Garcia-Ulloa J, Kühl HS, Humle T, Lee JSH, Koh LP. Will oil palm's homecoming spell doom for Africa's great apes? ***Current Biology*** 2014, ***24***(14): 1659-1663.

4. Sequeira AMM, Mellin C, Fordham DA, Meekan MG, Bradshaw CJA. Predicting current and future global distributions of whale sharks. ***Global Change Biology*** 2014, ***20***(3): 778-789.

5. Gutiérrez-Marco JC, García-Bellido DC. Micrometric detail in palaeoscolecid worms from Late Ordovician sandstones of the Tafilalt Konservat-Lagerstätte, Morocco. ***Gondwana Research*** 2014.

6. Mao M, Austin AD, Johnson NF, Dowton M. Coexistence of minicircular and a highly rearranged mtDNA molecule suggests that recombination shapes mitochondrial genome organization. ***Molecular Biology and Evolution*** 2014, 31(3): 636-644.

7. Mitchell KJ, Pratt RC, Watson LN, Gibb GC, Llamas B, Kasper M, et al. Molecular phylogeny, biogeography, and habitat preference evolution of Marsupials. ***Molecular Biology and Evolution*** 2014, 31(9): 2322-2330.

8. Cortez D, Marin R, Toledo-Flores D, Froidevaux L, Liechti A, Waters PD, et al. Origins and functional evolution of y chromosomes across mammals. ***Nature*** 2014, ***508***(7497): 488-493.

9. Necsulea A, Soumillon M, Warnefors M, Liechti A, Daish T, Zeller U, et al. The evolution of lncRNA repertoires and expression patterns in tetrapods. ***Nature*** 2014, ***505***(7485): 635-640.

10. Willerslev E, Davison J, Moora M, Zobel M, Coissac E, Edwards ME, et al. Fifty thousand years of Arctic vegetation and megafaunal diet. ***Nature*** 2014, ***506***(7486): 47-51.

11. Pearson RG, Stanton JC, Shoemaker KT, Aiello-Lammens ME, Ersts PJ, Horning N, et al. Life history and spatial traits predict extinction risk due to climate change. ***Nature Climate Change*** 2014, ***4***(3): 217-221.

12. Smith SJ, Wigley TML, Meinshausen M, Rogelj J. Questions of bias in climate models. ***Nature Climate Change*** 2014, ***4***(9): 741-742.

13. Elhaik E, Tatarinova T, Chebotarev D, Piras IS, Calò CM, De Montis A, et al. Geographic population structure analysis of worldwide human populations infers their biogeographical origins. ***Nature Communications*** 2014, ***5***.

14. Bradshaw CJA, Brook BW. Human population reduction is not a quick fix for environmental problems. ***Proceedings of the National Academy of Sciences of the United States of America*** 2014, ***111***(46): 16610-16615.

15. Thomson VA, Lebrasseur O, Austin JJ, Hunt TL, Burney DA, Denham T, et al. Using ancient DNA to study the origins and dispersal of ancestral Polynesian chickens across the Pacific. ***Proceedings of the National Academy of Sciences of the United States of America*** 2014, ***111***(13): 4826-4831.

16. Arsuaga JL, Martínez I, Arnold LJ, Aranburu A, Gracia-Téllez A, Sharp WD, et al. Neandertal roots: Cranial and chronological evidence from Sima de los Huesos. ***Science*** 2014, ***344***(6190): 1358-1363.

17. Lee MSY, Cau A, Naish D, Dyke GJ. Sustained miniaturization and anatomical innovation in the dinosaurian ancestors of birds. ***Science*** 2014, ***345***(6196): 562-566.

18. Mitchell KJ, Llamas B, Soubrier J, Rawlence NJ, Worthy TH, Wood J, et al. Ancient DNA reveals elephant birds and kiwi are sister taxa and clarifies ratite bird evolution. ***Science*** 2014, ***344***(6186): 898-900.

19. Lee MSY, Cau A, Naish D, Dyke GJ. Morphological clocks in paleontology, and a mid-cretaceous origin of crown aves. ***Systematic Biology*** 2014, ***63***(3): 442-449.

20. Fordham DA, Brook BW, Moritz C, Nogués-Bravo D. Better forecasts of range dynamics using genetic data. ***Trends in Ecology and Evolution*** 2014.

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