Do bacterial immune defences drive the recovery of threatened frog populations?

DONALD McKNIGHT
James Cook University, Townsville

Recent decades have seen major declines in amphibian populations throughout the world. Multiple factors are causing these declines, but one of the most important threats is an emerging infectious diseases known as amphibian chytridiomycosis. This disease is caused by the fungal pathogen *Batrachochytrium dendrobatidis* (or just *Bd* for short) which parasitises amphibians' skin and prevents them from maintaining a proper balance of water and salts, ultimately resulting in cardiac arrest. Currently, *Bd* can be found on every continent except Antarctica, and it has caused over 200 species to decline or even become extinct.

The Wet Tropics of Australia is one of the regions that has been heavily impacted by this disease, and in the late 1980s a large outbreak caused many frog populations in Queensland to disappear. However, not all species and sites were affected, and high elevation populations were particularly prone to declines. Thus, for several species such as the waterfall frog (*Litoria nannotis*) and the green-eyed treefrog (*Litoria serrata*), high elevation populations declined or disappeared, but populations below 300 metres survived and remained stable. Remarkably, in the time since the initial outbreak, many of the high elevation populations that had disappeared have come back, and these new populations seem to be stable, despite the fact that *Bd* is still present. Currently, no one knows how these populations recovered or why they are currently able to coexist with the pathogen. Therefore, the goal of my research is to determine how these populations have recovered, so that we can use that information to both manage current populations and aid other populations in recovering.

One of the most exciting possibilities is that populations have recovered by shifting their microbiomes. Amphibians have a rich collection of bacteria that live on their skin (collectively known as a microbiome), and laboratory trials have shown that some bacterial species are capable of fighting *Bd* infections. These studies found that giving the frogs additional beneficial bacteria resulted in the *Bd* infections being cleared, whereas individuals that were given

Above: Donald McKnight: Photo by Jen McKnight

A waterfall frog (*Litoria nannotis*) at a low elevation site. Photo: Donald McKnight antibiotics to reduce their bacteria were even more susceptible to the infection. Based on those results, it is possible that wild populations could coexist with the fungus if their microbiomes shifted to contain more beneficial bacteria, and that is what I am going to examine.

To test this hypothesis, I will compare the microbiomes of upland and lowland populations of waterfall frogs and green-eyed treefrogs. Because both of these species declined or disappeared at high elevation sites but remained stable at low elevation sites, this will let me see if the upland populations have recovered through changes in their microbiomes. In other words, if bacteria have played an important role in the recovery of the upland populations, then I expect those populations to contain disproportionately more anti-fungal bacteria than are contained in the low elevation populations. I am also going to examine the microbiomes of upland and lowland populations of the stony creek frog (*Litoria wilcoxii*), because this species occurs along the same streams as waterfall frogs and green-eyed treefrogs, but it did not decline at any elevation during the *Bd* outbreak. Therefore, this species will provide a control that will allow me to account for elevational differences that are being caused by factors other than *Bd*.

Collecting bacterial samples will be relatively straightforward. I will capture wild frogs along their streams, gently run a sterile swab along their bodies, then release them where I captured them. The more complicated component of this project will take place later, in the laboratory, where I will extract the bacterial DNA from the swabs, then sequence that DNA to determine which species of bacteria are present and how abundant they are. The funding from the Australian Wildlife Society has allowed me to purchase many of the chemical reagents necessary for this laboratory work, and I am grateful for their support.

The results of my project have the potential to be very useful for amphibian conservation efforts. For example, many biologists have suggested that we can help populations recover by seeding them with beneficial bacteria. So, by testing whether or not bacteria are already playing a role in the recovery of some populations, my study will help to shed light on the usefulness of this potential conservation strategy, as well as identifying candidate bacteria to use in recovery efforts.


Litoria nannotis. Photo: Donald McKnight


Litoria nannotis. Photo: Donald McKnight


Litoria nannotis. Photo: Donald McKnight

How does rainforest fragmentation affect the composition and feeding behaviour of a post-dispersal vertebrate seed predator community?

GARY PALMER
Griffith University

Rainforest fragmentation leads to a loss of original habitat, reduction in remnant size, and increasing isolation of remnants from each other. This can lead to significant changes to vertebrate species assemblages. Many terrestrial bird and mammal species are major seed predators in rainforests. Changes in abundance of vertebrate seed predators are likely to lead to altered rates of seed predation, thereby affecting the ability of fragments to maintain original patterns of plant recruitment. Most research investigating the effects of fragmentation on vertebrates has focused on mammal or bird community composition, irrespective of diet. The general finding of this research is that responses to fragmentation are complex and highly variable. However, species composition of vertebrate seed predator communities, as well as the effects of fragmentation, has received little attention.

Much of the subtropical lowland forests of southern Queensland and northern New South Wales have been cleared or converted for agriculture (and some to forestry plantations) from the mid-19th century. The 'Big Scrub' is a region of highly fragmented subtropical rainforest in north eastern New South Wales. Agricultural development of the Big Scrub region began in the late 1800s, resulting in significant land clearing. Remnants of the Big Scrub are scattered across a highly modified landscape, largely consisting of livestock pasture, together with substantial areas of macadamia tree plantations, as well as woody forest regrowth. The remaining areas of original rainforest are estimated to be between 300 ha and 556 ha in total area, or 0.4% to 0.7% of the original 75,000 ha rainforest cover.

Rainforest fragments in the Big Scrub, surrounded by agricultural land.

Using video footage from infra-red camera traps, this study will for the first time identify the species composition of a post-dispersal vertebrate seed predator community across a range of common rainforest tree species, and also quantify the level of interactions between seed predators and seeds. The effects of rainforest fragmentation on both the species composition of the seed predator community and levels of interactions between predators and seeds will also be investigated. Understanding the consequences of fragmentation for seed predators and subsequent rates of seed predation is important for ongoing conservation management.

This project will provide information to help manage fragmented rainforests and thereby improve the likelihood that various rainforest tree species are able to persist over the long term.

Rainforest fragments in the Big Scrub, surrounded by agricultural land.

Hannah releasing a possum after processing

Factors influencing the population persistence of brushtail possums (*Trichosurus vulpecula*) in a semi-arid environment

HANNAH BANNISTER
The University of Adelaide

'Common' brushtail possums (*Trichosurus vulpecula*) have significantly declined over the past 200 years, particularly in arid and semi-arid areas, having totally disappeared from more than 50 percent of their historical range. Brushtail possums are listed as 'Rare' in South Australia (*National Parks and Wildlife Act 1972*) and their population trend is listed as 'decreasing' by the International Union for Conservation of Nature (IUCN). Along with habitat loss, competition with introduced and domestic herbivores and persecution, predation by introduced predators is one of the key contributors to their decline. In the Ikara-Flinders Ranges National Park, in semi-arid South Australia, introduced foxes (*Vulpes vulpes*) are successfully controlled through the *Bounceback* program (DEWNR). The suppression of foxes led to a trial reintroduction of brushtail possums to the park in 2015, where they had not been present since the 1940s. With reintroduction projects often failing, it is vital to understand factors that may influence reintroduction success and ultimately population persistence.

Habitat requirements for brushtail possums vary greatly depending on the environment they are found in, and few studies have been conducted on brushtail possum ecology in semi-arid environments. Perhaps most important for the reintroduction and for remnant brushtail possum populations is the ability of the offspring of the founder population to survive, disperse and reproduce; that is, the ability of the population to persist. In Australia, few studies have focused on monitoring the survival and dispersal of juvenile brushtail possums, and this could provide an insight into potential threats to long-term population persistence as well as identifying key actions to be undertaken for conservation of the species in remnant and reintroduced populations. The primary objective of this research is to identify factors that may affect the short- and long-term persistence of brushtail possums in the Ikara-Flinders Ranges National Park following their reintroduction. My main aims are: (1) to determine which habitat features are necessary for population persistence of brushtail possums in a semi-arid environment, and (2) to understand the ecology of juvenile brushtail possums, including their survival, age and weight at dispersal, when reproductive maturity is reached and their movements in relation to their maternal home range.

To achieve this, I will be monitoring the types of shelter sites used by radio-collared possums. Additional information on canopy connectivity, mid-storey abundance, plant species diversity, distance to water and basal area of trees will also be recorded along with the movements (home range) of individuals. I will also be radio-collaring successive juveniles from a focal group of thirteen females to monitor their movements and survival – once out of the pouch, juveniles can be fitted with a small 7g radio-transmitter. A small number of home-made GPS collars, cheaper than traditional GPS collars, will be constructed using VHF transmitters and commercially available GPS data loggers. These collars will be used to collect home range information and to compare the location of females with their offspring, once dispersed, at regular intervals. By improving our understanding of the requirements for brushtail possums to persist in semi-arid environments we may not only improve reintroduction success but may also inform management decisions regarding the conservation of the species, which should no longer be considered the 'common' brushtail possum.

A female and her dependent young (5.5 months old), both radio-collared to monitor movement and survival. Juveniles may be particularly vulnerable to predation – this dependent juvenile (aged 6 months) was killed by a feral cat a week after this photo was taken.

Spying on dingoes in the desert:

How do they behave and where do they go when no one is looking?

JACK TATLER
The University of Adelaide

Remote monitoring technology is an undeniably powerful tool for furthering our knowledge of the natural world. In recent decades, outstanding developments in the reliability, accuracy and scope of remote monitoring technology has provided researchers with the means to quantitatively measure an animal's behaviour and physiology whilst in the wild. Data collected from these animal-attached sensors can be translated into behavioural states such as walking, running and hunting, and can also be used to make interpretations about daily energy expenditure. Furthermore, fine-scale location data obtained from similarly attached GPS devices can be used in conjunction with environmental variables to explain how animals selectively use resources within their geographic range. The value in understanding behaviour, energy expenditure and resource selection by animals is that it can be used to guide management and conservation over broad extents and diverse habitats.

Dingoes are an iconic and ecologically important species in Australia. Unfortunately, quantitative data on the behaviour, energetics and resource selection of free-ranging dingoes is all but absent from the literature, yet is fundamental to predicting how they will interact with management strategies, habitat destruction, native species and reintroduction endeavours. This project aims to quantify behavioural states, measure behavioural complexity and determine the drivers of habitat selection and movement patterns of free-ranging dingoes.

Our study site is located approximately 900 km north of Adelaide at

Warburton River with water from January rain.

Kalamurina Sanctuary, a 667,000 ha expanse of land owned and run by the Australian Wildlife Conservancy. Much of the landscape is characterised by elongated parallel sand dunes but there are also a diversity of ecosystems including freshwater lakes, desert woodlands and riparian floodplains. In April 2016, we successfully deployed 10 custom-made Iridium GPS collars with inbuilt accelerometers and temperature sensors on adult dingoes (6 females and 4 males).

We have received high-quality data from 9 of our 10 collared dingoes (one collar failed after release) and they are scheduled to drop off at the end of August. These dingoes have remained relatively close to their point of capture, with seven concentrating their movements along the Warburton River, which is one of the only sources of free water (that is not hypersaline) on the entire sanctuary). All dingoes are exhibiting home-range philopatry; five occupy overlapping home ranges and four clearly avoid those areas inhabited by other collared dingoes. Sand dune swales and paleo-drainage lines appear to be important corridors for dingo movement throughout the landscape. Home-range size and average movement distance are smallest for dingoes using densely vegetated habitat along the Warburton and largest for individuals occupying open, sand dune-dominated habitat.

We are currently collecting accelerometer data from captive dingoes at Cleland Wildlife Park, which we will combine with direct observations to classify behavioural classes. We will access the accelerometer data from free-ranging dingoes once the collars are retrieved in September and assign behavioural classes to the data by using the model we created from captive dingoes. We will also measure the complexity of the accelerometer/behavioural data in order to link physiological function with ecological processes. Six more GPS collars were deployed in September 2016 and up to ten more in April 2017. It is important to track dingoes throughout the year in order to assess how habitat selection and behaviour change throughout time and with considerable variation in available resources.

Jack Tatler radio-tracking dingoes at Kalamurina in April 2016.

Jack Tatler installing a humane foothold trap to catch a dingo.

Potential impacts of western quolls (*Dasyurus geoffroii*) on in situ species at Arid Recovery

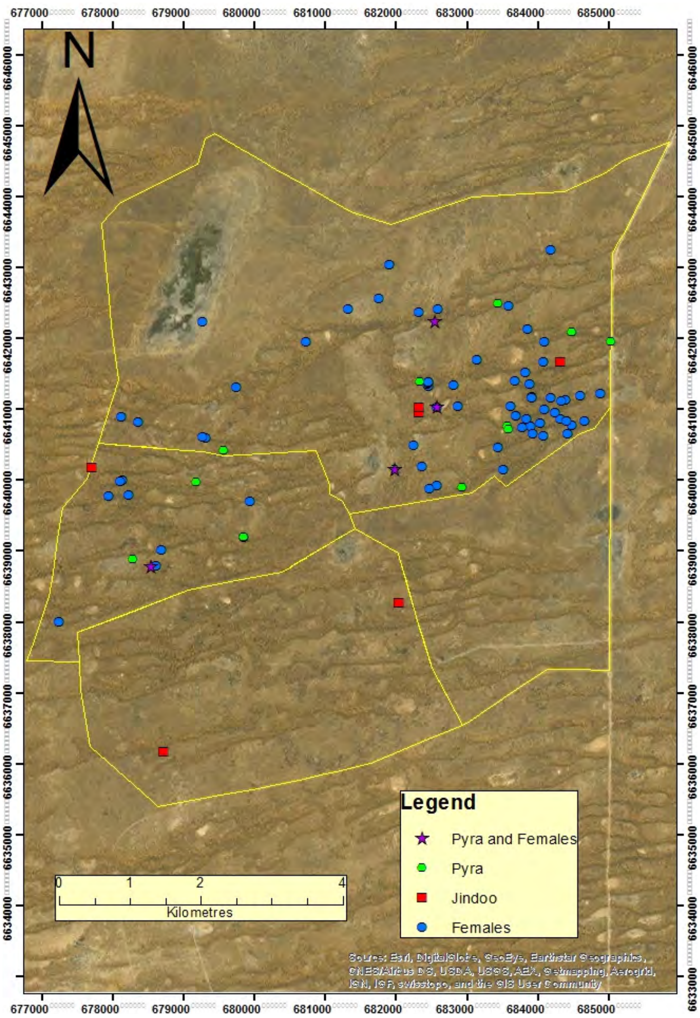
LUKE TILLEY
The University of Adelaide

The western quoll, once found throughout the majority of the Australian continent, has now been restricted primarily to the jarrah forests of south-west Western Australia. After the success of a 2013 reintroduction program in the Flinders Ranges (South Australia), it was proposed that a population could also be established at Arid Recovery (South Australia). Apart from the potential to see the return of the species to an arid habitat, the quolls could also be highly beneficial to the reserve, with an overpopulation of the burrowing bettong a key management concern.

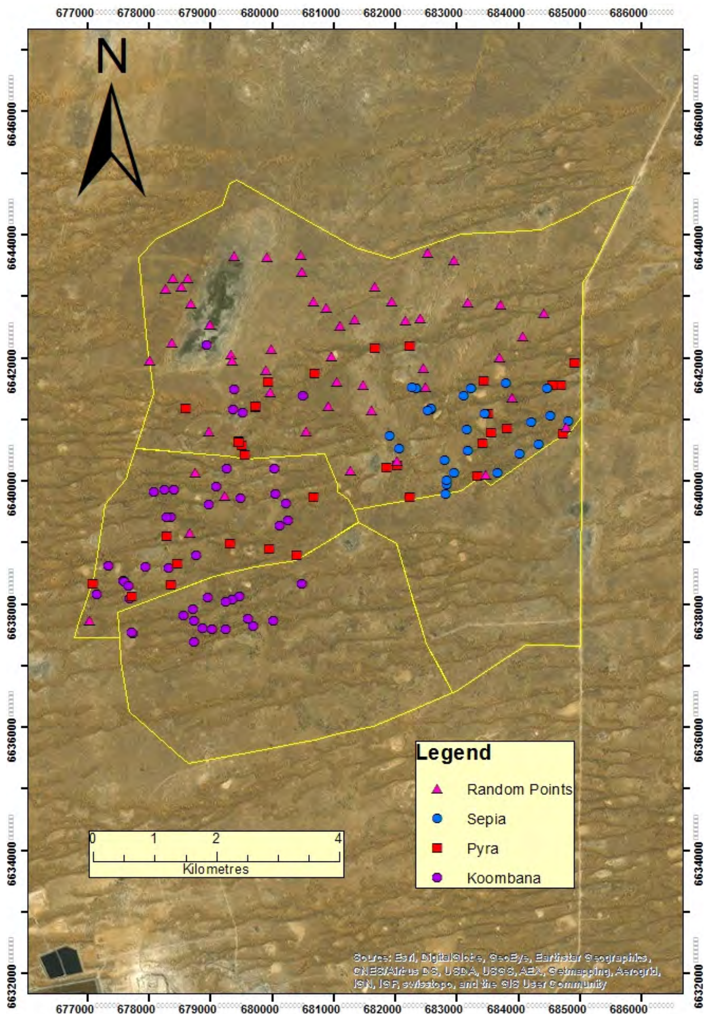
This project aims to determine what the potential impacts of reintroducing the western quoll to Arid Recovery could be on the four nationally threatened species, burrowing bettong (*Bettongia lesueur*), greater bilby (*Macrotis leucura*), western barred bandicoot (*Perameles bougainville*) and greater stick nest rat (*Leporillus conditor*). Previous research has indicated that the western quoll is an opportunistic predator, and thus the hope is the species will not have a significant impact on the populations of more vulnerable species like the greater stick nest rat (small body size and low abundance within the reserve), and possibly help contribute to reducing the population of more problematic species like the burrowing bettong.

Two male quolls (named Pyra and Jindoo) were released into the reserve

Western Quoll Shelter Site Locations Within Arid Recovery



Western Quoll Habitat Use Within Arid Recovery



during May 2016, to accompany two females (Sepia and Koombana) released in 2015. The four quolls were radio-tracked to daytime shelter sites using VHF collars. Characteristics of 87 shelter sites the quolls are known to have used were collected, as well as 74 available shelter sites within the reserve. Characteristics of 100 (33 male and 67 female) used habitat points and 50 randomly generated habitat points were also collected using GPS pin point collars fitted to the quolls for a duration of three weeks each. Both used and available shelter sites and habitat points will be compared to determine if there are any factors the quolls are selecting for, that are likely to contribute to a negative impact on the other reintroduced species within the reserve. Scats were collected by visiting shelter sites, and searching for latrines, in order to analyse diet.

Unfortunately, one of the males (Jindoo) escaped the reserve within two weeks of release, and was unable to be relocated despite extensive efforts to radio-track aerially. The scats collected during this project are still being analysed by Desert Wildlife Services, but results from 2015 indicated the female quoll diet contained spinifex hopping mice (*Notomys alexis*), juvenile bettong and western barred bandicoot. The scats collected in this project will help to confirm if male quolls have the potential to target different species or species at a varying frequency, with n=33 scats collected from the male (Pyra) that remained within the reserve.

Shelter site and habitat data indicates the quolls are spending 90 percent of their time in dune habitat and also prefer to shelter in dunes, over swale habitat. They shelter within bettong warrens and burrows (predominantly warrens). Only one greater stick nest rat nest was utilised by a male quoll for shelter (not believed to be active at the time) and habitat usage thus far does not seem to bias the location of nests. Classification trees will be used to look at fine-scale habitat and shelter preferences and confirm this. An honours thesis on this project is due to be submitted on 26 October 2016.

A positive sign for any future full-scale reintroductions is that the quolls can successfully breed within the reserve, with female Sepia now the proud mother of four pouch young.

Sepia, a female quoll with a GPS collar attached. Photo by Elizabeth Florance, 2015.

Rebecca West (Supervisor) with Pyra.

Dr Rebecca West (UNSW) discovering the first four quolls born within Arid Recovery to mother Sepia and father Pyra (Rebecca West, 2016).

Interactions between native and invasive grass species and the role of soil microbes in grassland restoration

MONIQUE SMITH
School of Biological Sciences,
The University of Adelaide

Lowland temperate grasslands and open grassy woodlands have been labelled Australia's most threatened ecosystems with around only one percent remaining. Large-scale clearance of these habitats occurred mostly due to the suitability of such areas for agriculture. As a result, restoration of grassy habitats is needed to conserve these unique ecosystems and the organisms that inhabit them. Areas of farmland that was previously cultivated and now abandoned (old-fields) are difficult to restore as they lack a native seed source and are often overrun by invasive plants. These areas also suffer from increased nutrient availability and soil compaction due to past farming practices, resulting in unfavourable conditions for native plants. These properties of old-fields can also affect the soil microbial community, which in turn has the potential to further reduce the success of restoration attempts.

Soil microbes, particularly fungi and bacteria, can affect plants either positively or negatively through pathogenic effects, aeration of soils and controlling nutrient cycles. Symbiotic relationships between plants and microbes are very important for plant growth and establishment, with around 80 percent of vascular plants relying on soil microbes to aid nutrient uptake in exchange for organic matter to feed on. Weed invasions can create feedback loops whereby the invasive plants create conditions favourable to their soil microbe symbionts, giving them a further advantage over native plants. Researchers and restoration practitioners are beginning to consider how soil microbes may be utilised to improve restoration outcomes. This is a relatively new approach and so much is still unknown on the importance of soil microbes for grassland restoration.

This is where my Ph.D. research comes in. I have carried out a glasshouse experiment to investigate the effects of changes in soil microbial communities on native and invasive grass growth. I compared the performance of two native (*Rytidosperma auriculatum* and *Austrostipa nodosa*) and one invasive (*Lolium rigidum)* grass species grown in the presence of three different soil microbial communities. One of these communities was collected from an old-field dominated by the invasive

Soil was taken from a seed orchard like this one to see whether the microbial communities under the monoculture of native grasses can improve the success of future restoration projects. The results found that remnant soil microbes were much better for native grass performance. Photo: Andrew Fairney grass *Avena barbata*, another was from a remnant grassland, and the third soil microbial community was from an orchard of native grasses. I used this experiment to test the following questions:

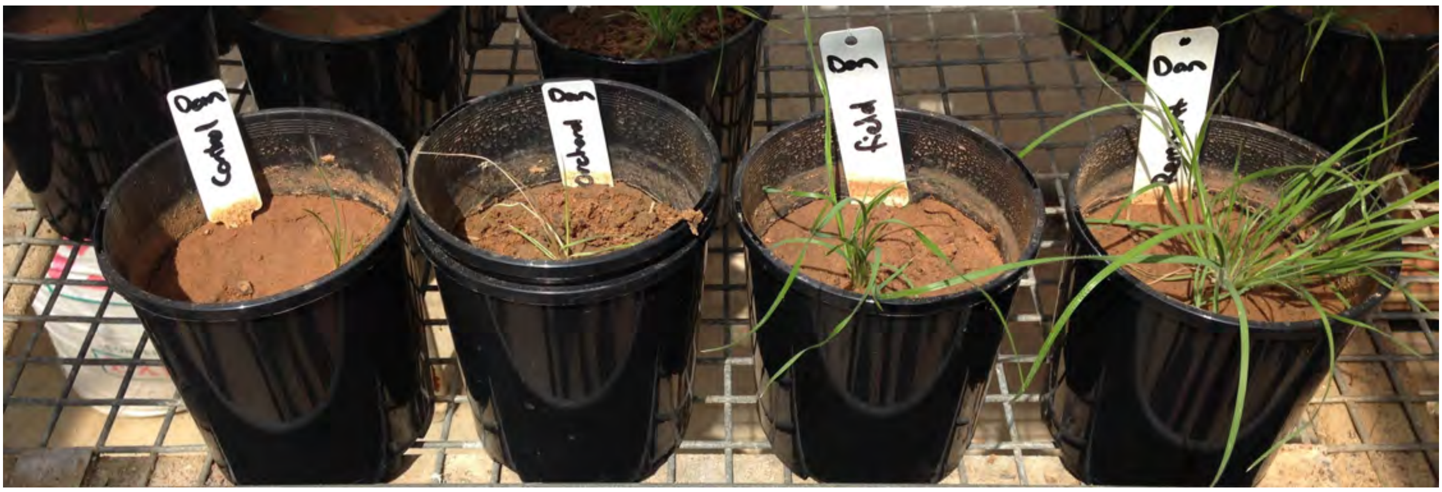
- Does the presence of one invasive grass aid establishment of other invasives? If so, is this a result of changes to the soil microbial community?
- Does native grass growth and establishment benefit from the presence of remnant microbial communities?
- Does planting in a monoculture of native species produce microbial communities that improve the success of future restoration projects?

My results indicate that the microbes present in soil collected from the remnant area improved native grass performance with increased growth (see picture below) and lowered mortality. The orchard soil microbes did not appear to be a suitable replacement for remnant microbes, with reduced growth in plants growing in the presence of these microbes. This suggests that planting in a monoculture of natives may not be sufficient for creating conditions suitable for a diverse microbial community. Native plants grown in the presence of soil microbes from the old-field had the highest mortality (up to 60 percent in one native grass). This leads to less effective restoration outcomes and a lowered reproductive output. The invasive species, on the other hand, appeared to not discriminate between microbial communities, growing just as well in soil containing old-field microbes compared to those grown with remnant microbes.

Grass-dominated systems, such as this open grassy woodland, are among our most threatened systems in Australia. This photo was taken at my field site, Para Woodlands Reserve, South Australia, where the remnant soil was collected and where my field trials take place. Photo: Dragos Moise

So, to improve restoration success in old-fields and to reduce invasion by weed species, consideration and management of below-ground biota may be critical to native plant growth and establishment. Taking soil microbes from remnant areas and inoculating old-fields with them may help to reduce the mortality of replanted communities and give them a competitive edge against invasive species. In order to get a better understanding of the differences in these soil microbial communities, I am now using a technique called DNA metabarcoding to assess what microbial species are found in the different soil types. This will help us to identify which soil microbes may be important for the native grasses.

Thanks to the funding from the Australian Wildlife Society, I will be heading to Europe later this year, where I will be sharing these results with an international audience at the British Ecological Society Annual Meeting in Liverpool, United Kingdom. Whilst there I will also be visiting two research groups, one at the James Hutton Institute in Dundee, Scotland and the other at the University of Tartu in Estonia. These lab visits will give me insight into the methods used by other groups for addressing similar questions to mine and this should hopefully improve the analysis of and outcomes from my own research.



The picture above demonstrates the difference in growth of the native grass Rytidosperma auriculatum when grown in a sterile control, or with microbes from a monoculture of a native grass, an old-field or a remnant site (pots left to right, respectively, and labelled control, orchard, field and remnant).

Investigating correlates of *Toxoplasma gondii* infection to explain its higher seroprevalence on Kangaroo Island

PATRICK TAGGART
The University of Adelaide

Why does *Toxoplasma gondii* like the island life?

Toxoplasma gondii is a parasite which causes the disease toxoplasmosis. This parasite is carried by and sexually reproduces in species of the feline family, including domestic cats. In Australia, the only host within which *Toxoplasma gondii* can sexually reproduce is the domestic cat (*Felis catus*). The cat is termed the primary or definitive host. Following their first infection with *T. gondii,* cats pass an infective egg-type stage of the parasite, the oocyst, into the environment. These oocysts are extremely hardy and can last for a long time in the environment, up to 18 months, much longer than the faeces itself! Wildlife subsequently become infected by consuming food, water or soil contaminated with infective oocysts. *Toxoplasma gondii* is also said to be able to infect all warm-blooded animals, and causes significant and debilitating disease in wildlife, livestock and even humans! Australian marsupials are particularly susceptible to toxoplasmosis compared to wildlife in other countries. Scientists attribute this to Australian wildlife evolving in an environment free from cats, and hence, the parasites they unwittingly carry.

Toxoplasmosis can cause a huge array of symptoms in wildlife, including blindness, incoordination and death. Some of the symptoms, such as blindness, incoordination, and other neurological problems, make animals more susceptible to predation, assuming, of course, the disease doesn't kill them first. There is also preliminary evidence that *T. gondii* infection may induce behavioural changes in wildlife that make animals more risk-averse, similar to how *T. gondii* infection causes mice to lose their innate fear of cats. It is thought this symptom occurs to encourage prey to be eaten by cats to perpetuate the life cycle of *T. gondii*.

On Kangaroo Island in South Australia, a very high rate of *T. gondii* infection has been shown in cats and sheep, among the highest recorded from any Australian location. This high rate of infection in cats and sheep on Kangaroo Island is concerning as it suggests a high and sustained level of environmental contamination with infective oocysts. This exposes threatened and endemic Kangaroo Island wildlife, such as the

A feral cat on Kangaroo Island. The cat is termed the primary or definitive host of *Toxoplasma gondii.*

Re-establishment of Providence petrels (*Pterodroma solandri*) on Norfolk Island

ANICEE LOMBAL
PhD Candidate, University of Tasmania

Seabird translocations are being increasingly proposed during the past decade in response to the large number of seabird species threatened with extinction throughout the world (28 percent). Nevertheless, information on population mixing among seabird colonies is crucial in assessing the genetic risks posed by this method of conservation (e.g. reduced genetic variation, genetic load or outbreeding depression).

The Providence petrel (*Pterodroma solandri*) is IUCN listed as Vulnerable due to its restricted breeding range. The only significant breeding locality of this species of pelagic seabird (approx. 32,000 breeding pairs) is Lord Howe Island, a small island off the eastern coast of Australia. Providence petrels used to breed on Norfolk Island (approx. 1,000,000 breeding pairs) before becoming extinct after European settlement by the late 18th century. The species was considered extinct within the Norfolk Island group until 1986 when a small population (approx. 20 breeding pairs) was discovered on Phillip Island, seven kilometres south of Norfolk Island. Re-establishment of a Norfolk Island colony using Lord Howe Island individuals has been proposed to reduce the extinction risk of this species and to provide key nutrients for the regeneration of threatened native forests and associated species. However, this translocation may erode any distinctiveness of the small adjacent Phillip Island colony, which shows a specific behavioural adaptation to diurnal predators.

The study used molecular data to investigate genetic connectivity among Providence petrel colonies and quantify the age of divergence between populations in order to assess the maximum possible duration across which differences in roosting behaviour developed. Primary results show a high gene flow between colonies and limited risks associated with this conservation

Providence petrels at their nesting sites.

Anicee Lombal presenting her research on the re-establishment of Providence petrels on Norfolk Island at the Sixth International Albatross and Petrel Conference in Barcelona.

Anicee Lombal holding a Providence petrel on Lord Howe Island.

management plan. If this translocation occurs, the resulting increase in marine-sourced nutrients would assist in halting and reversing the decline of Norfolk Island's native forest and associated fauna, which includes many other imperilled birds (e.g. the endangered Norfolk Island green parrot (*Cyanoramphus cookie*).

This study provides crucial information on an understudied Australian species, an indicator of human-induced change, which is fundamental to the understanding and management of our environment. The Australian Wildlife Society has assisted in conserving the Providence petrel by enabling the presentation of my research at the Sixth International Albatross and Petrel Conference in Barcelona. This meeting was a fantastic opportunity to interact with an international group of scientists with similar interests to my research topic in order to have access to their expertise on the re-establishment of this key species on Norfolk Island in the near future.

I thank the Australian Wildlife Society for its generous support.

Providence petrels flying around their nesting sites at dusk.

Mapping the distribution of the European rabbits (*Oryctolagus cuniculus*) in Australia using occurrence data from targeted and non-targeted field studies

EMILIE ROY-DUFRESNE
Adelaide University

Invasive species are a major driver of global change, presenting an enormous threat to biodiversity today and in the future. One of the most notorious introduced species in Australia is the European rabbit (*Oryctolagus cuniculus*). The rabbit is listed among the world's 100 worst invaders by the Invasive Species Specialist Group (www.issg.org). It was introduced on the continent with the First Fleet in 1788 and, since then, its populations have caused extensive damage to the Australian wildlife. The distribution and abundance of many native species of plants and mammals are considerably affected by the pressure exerted by the heavy presence of rabbits. This includes issues from competition, high population density, heavy grazing, and soil erosion. Their occurrence in Australia is considered a threat to the management and regeneration of native wildlife and wooded rangelands.

The presence of the European rabbit in Australia has been studied considerably since its introduction. Until now, scientists and expert managers have conducted close to 300 studies of the species. The aim of the majority of these studies was to investigate different methods to evaluate the rabbit population size and to measure the impact of control measures on its population density. Nonetheless, no attempt was made to model the distribution of rabbit populations in Australia using both climatic and environmental variables.

To remedy this situation, I recently compiled a large database which includes data from more than 100 studies describing over 50 years of rabbit occurrence in Australia. To estimate the rabbit geographical ranges, I used distribution models which statistically relate the occurrence records of the rabbit to the environmental conditions found where those records were taken. I therefore matched the records in the database to climatic and environmental predictors, with the aim to document important trends in the distribution of rabbits in Australia. The datasets contained in the database come from diverse sources. It includes data collected by biologists and management experts, data obtained from museums and state-based collections, and data collected by citizens as part of the Feral Scan program. While the collection of most of these data followed a pre-established scientific field protocol, others such as the citizen science data

European rabbit (*Oryctolagus cuniculus*), Freemantle, 2015. Photo: Michael Graham Stead (PhD student at Adelaide University).

Rabbit plague, Quinyambie Station North East, South Australia, 1988. Photo: Peter Bird.

Emilie extracting a rabbit from a trap during a capture-mark-recapture study with Biosecurity SA, Barossa Valley, 2015.

are opportunistic and do therefore not follow a standardised field protocol.

Although more recurrently recorded in online databases, the citizen science datasets in science remain a source of constant debate, especially when creating a model of distribution. One of the main reasons for this is commonly referred to as sampling bias. Sampling bias occurs when a data sample is collected in such a way that one characteristic of the data is more frequently represented than the others. For instance, some sites tend to be visited more often than others because they are more accessible (i.e. near roads and towns) or offer greater naturalistic interests. In the case of the data obtained from the Feral Scan program, it is easy to identify major roads and cities in Australia while exploring the distribution of recorded sightings on a map. This sampling issue has consequences for the ecological information gleaned from the data and can lead to errors in a statistical model. The model will associate these regions with a higher probability to observe the species, while in reality the regions represent areas where more data were sampled. Nonetheless, the network of citizen scientists has the potential to observe species at a broad spatial and temporal scale, which would be logistically or financially unfeasible to achieve with traditional field sampling methods. Data contributed by citizen scientists therefore remain valuable for modelling the distribution of species, especially while attempting to cover an entire continent.

This research was driven by the need to model the distribution of rabbits in Australia in order to support the implementation of effective population control measures. In addition, the inclusion of a diverse range of datasets opened new avenues for modelling. Several methods are now proposed in the scientific literature to correct for sampling bias. The first objective of this research is therefore to investigate how data coming from opportunistic citizen science programs, such as the Feral Scan data, can influence the outcome of our distribution models. In this project I ask if, by controlling for the uncertainties associated with the provenance of this data, I can improve the accuracy of the models compared to models that ignore the additional data. The second objective of the research is to evaluate the potential role of opportunistic citizen data to fill spatial and temporal gaps in the datasets where no other type of data was collected, and again how it can influence the outcome of the models.

The outcomes of this research will have several significant implications. In terms of rabbit management in Australia, the results of the models will help experts understand the ecological characteristics of rabbit populations in their introduced ranges. Moreover, results will promote a better approach to the management and monitoring of the species across Australia. By

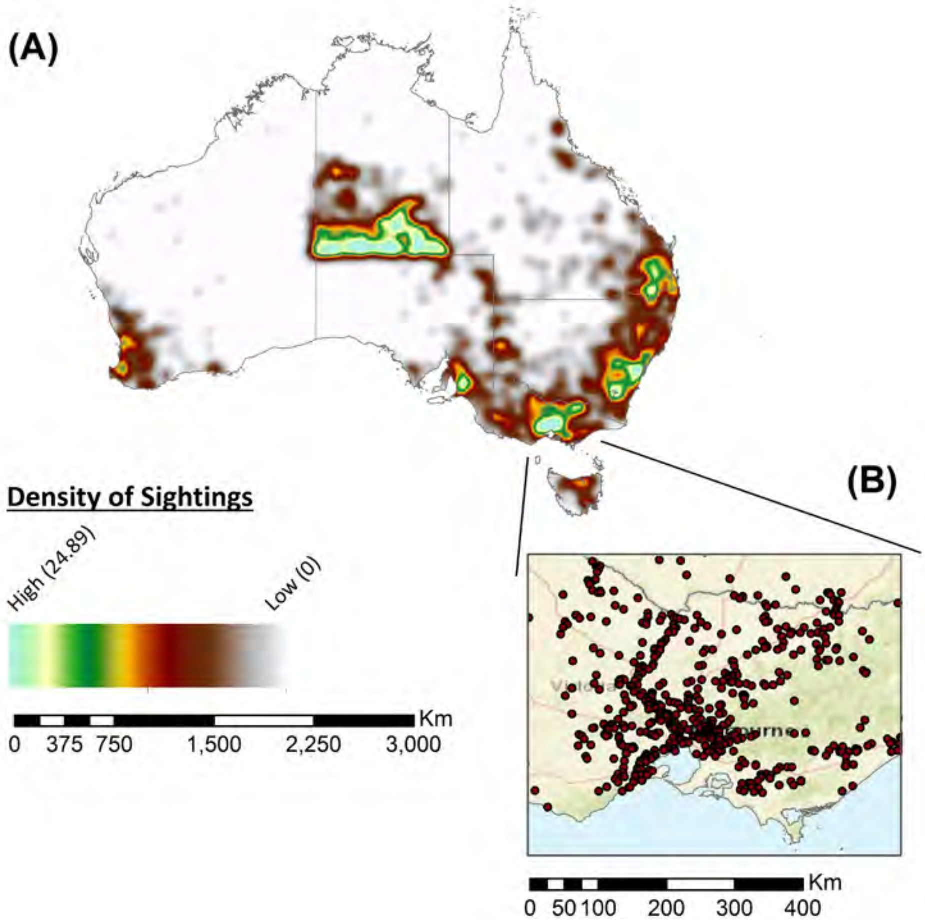


Figure illustrating: (A) The density of sightings from the citizen science program, (B) Sampling bias of the citizen data around the city of Melbourne.

providing a map of where rabbit populations can be observed across the country, the project helps target control measures and consequently contributes to a reduction of the species' impact on native wildlife populations. The results from the models will also provide evidence on how uncertainties associated with citizen data sampling can be accounted and adjusted for in different distribution models.

I recently finished the calculations for statistical analysis to build and run the models and am currently in the process of analysing the results.

Thanks to the funding from the Australian Wildlife Society, I was able to present the first results of the analysis at the Australian Wildlife Management Society Conference in Auckland, New Zealand. I hope that by sharing this research, I will stimulate more discussions about the management of rabbits in Australia. At the same time, I am also excited at the opportunity to gain insights into the methods other research groups use to address the issue of spatial bias in citizen science data. I believe that despite these biases, it is important that we take advantage of the quantity of data accumulated and the efforts volunteers undertook to the benefit of science.

Rabbit warren characterised by heavy grazing and soil erosion, Barossa Valley, 2015.

Barossa Valley landscape

"We've had a gutful of this rubbish" The population level effects of plastic ingestion in Australasian seabirds

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Seabirds are the world's most threatened group of birds, with nearly half of the world's species experiencing population declines, and 28 percent are globally threatened. According to the IUCN Red List, of the 66 Australasian Procellariiformes (tube-nosed) seabirds, including albatross, petrels, prions and shearwaters, almost 40 percent are threatened with extinction. Understanding the threats to seabirds in their environment is critical to planning effective conservation and management strategies for these species if we hope to manage and reverse these trends.

Ingestion of plastics floating in the marine environment is a widespread emerging threat to marine birds who mistake the floating plastics for food. With an estimated five trillion plastic pieces floating in the world's oceans currently, and more entering daily, the threat floating plastics pose to marine birds only increases with time.

Despite the potentially significant conservation issue that marine debris ingestion poses to Procellariiformes globally, very little is known both of the extent of plastic ingestion among Australasia's 66 Procellariiformes species, and nothing is known of population-level impacts globally. My PhD study aims to both identify the extent of marine debris ingestion across all Procellariiformes families, and model the impact of marine debris ingestion across Australasian seabird populations.

To survey marine debris ingestion in wild seabirds, we collect and perform necropsies on dead seabirds from a variety of sources. Many of the seabirds are collected dead on the beach, but we also are assisted by carcass donations of casualties from veterinary clinics, museum collections and the carcasses of seabirds by-caught in fisheries. As we cannot patrol all beaches at all times, this study heavily relies upon volunteers throughout Australia and New Zealand to assist with collecting carcasses. We have been very privileged to have many interested people volunteering their time (and their freezers!) to assist us, including wildlife interest groups, park rangers, wildlife veterinary hospitals, museums and enthusiastic individuals throughout Australasia.

This year I was lucky to be selected for an Australian Wildlife Society University Student Grant to travel to New Zealand in September 2016 to collect and perform necropsies on seabird carcasses that had been collected by volunteers over the past 12 months. Bird carcasses were collected from across New Zealand from 90 Mile Beach in the north down to Invercargill in the south by the Ornithological Society of New Zealand's Beach Patrol Scheme, Wildlife Management International, Auckland Museum, Te Papa Museum, Holistic Vets and a number of individual collectors. Hundreds of individual carcasses spanning 20 seabird species were collected, from the tiny diving petrel (*Pelecanoides urinatrix*) to the large white-capped albatross (*Thalassarche steadi*).

The timing could not have been better for collecting seabird carcasses. During August 2016, persistent winds and storms west of Auckland caused a mortality event (often called a 'wreck') of prions, which are small plankton-feeding seabirds. Prions are one of the seabird groups we are particularly interested in as they are a species we don't often

Gizzard of a fairy prion containing hard plastic.

Above: Lauren measuring mixed seabirds collected by members of the Ornithological Society of New Zealand's Beach Patrol Scheme.

receive in large numbers, but those we do receive often have plastic ingestion. This seabird wreck presented the perfect opportunity to examine the prevalence of plastic ingestion among prions. The wreck event affected mixed species of prions, predominantly fairy prion (*Pachyptila turtur*) and slender-billed prion (*Pachyptila belcheri*), with a small number of Salvin's prion (*Pachyptila salvini*), Antarctic prion (*Pachyptila desolata*) and broad-billed prion (*Pachyptila vittata*), with a total of about 300 beach-washed prions collected.

We found plastic ingestion among all prion species examined, all shearwater species examined, some petrels and to our surprise, none of the albatrosses. Salvin's and slender-billed prions took the cake for the most birds affected with greater than two out of three individuals containing ingested plastics. The highest number of items we observed in a single bird was a sub-adult male slender-billed prion who

Plastic items removed from the gizzard of a short-tailed shearwater.

Lauren at Auckland Museum with mixed species of beach-washed prions collected by volunteers throughout New Zealand's North Island.

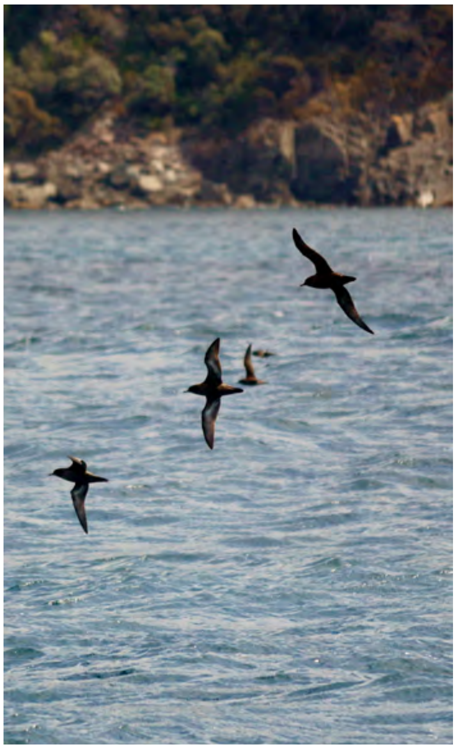
had ingested 21 pieces of hard plastic. An adult male short-tailed shearwater (*Ardenna tenuirostris*) took out second place with 19 items (mostly hard plastic). The largest item we found was a piece of blue balloon, also ingested by a slender-billed prion.

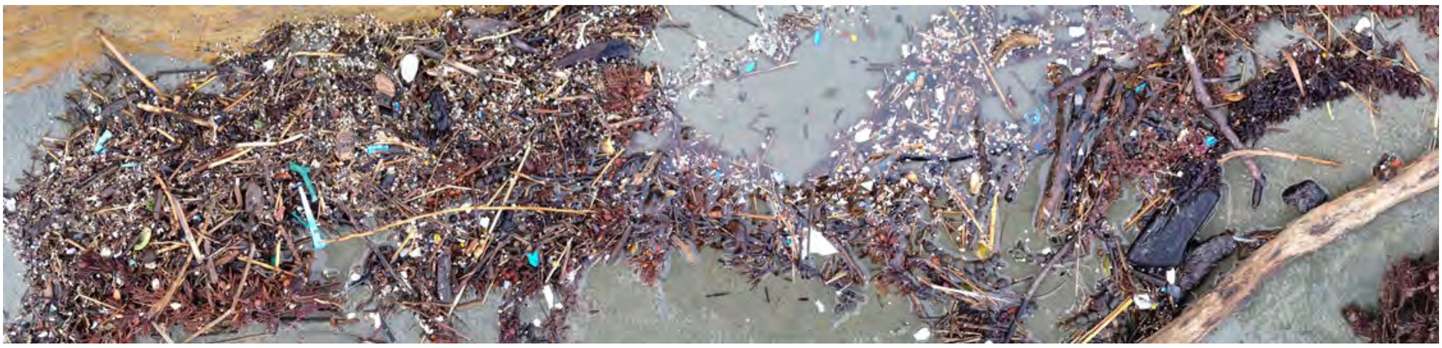
We are grateful to the Australian Wildlife Society and their contributors for the opportunity to travel to New Zealand to study plastic ingestion in these seabirds, adding valuable data to the picture of plastic ingestion in Australasian seabirds. We are also grateful to the collectors throughout Australia and New Zealand, as we could not do this valuable research without their contribution. For those who would like to follow the progress of this study, we have a Facebook page which we regularly update with photos and information about seabirds and plastic ingestion. You are welcome to follow the progress of this study at: https://www.facebook.com/seabirdsdebris/


Fairy prion at sea.


White-capped albatross


Juvenile white-capped type albatross at sea.


Short-tailed shearwaters at sea.


Plastic on the shore line of a New Zealand beach.