PROJECT TITLE: Backyard Bandicoots: engaging community in urban bushland conservation

AIM We will use an iconic ecosystem engineer to increase community involvement and engagement with conservation actions, contributing to increased connectivity and improved quality of urban bushland habitat. Our three **project objectives** are to:

1. Identify how southern brown bandicoots ('quenda') contribute to healthy urban bushland through dispersal of mycorrhizal fungi
2. Identify habitat use by quenda, using the latest technology to track and monitor animals
3. Identify and mitigate threats to quenda

OUTCOMES of this project include:

- Scientific: social and biological data collection
- Community: increased community involvement in local fauna and natural resource conservation
- Management: engage more urban residents with conservation of their local urban bushland; initiate long-term monitoring and conservation action through citizen science

(* indicates publications of the CIs)

BACKGROUND: We need to carefully consider how we shape the future of urban parkland to retain the quality of life that Australians currently experience. A marked population increase in Western Australia (WA) over the last two decades has resulted in substantial urban sprawl. Perth now stretches along the coast over 120 km from north to south. This urban sprawl encompasses the City of Mandurah (Industry Partner) to the south, the fastest growing regional city in Australia. This population explosion has rapidly changed the landscape to a sea of buildings and roads. However, there are still at least 1,000 isolated patches of remnant native vegetation within the Perth urban footprint – vital bushland spaces for our persisting plant and animal biodiversity, and to serve community as parks.

We believe that digging mammals can play an important role in maintaining healthy urban bushlands. These ecosystem engineers turn over substantial volumes of soil as they dig to forage on invertebrates, subterranean fungi, and plant material. Their digging activities drive ecosystem processes such as soil formation, water infiltration, nutrient cycling, and seedling recruitment (Davidson et al. 2012; Eldridge et al. 2012; *Garkaklis et al. 2004; *Moore et al. 2014). Additionally, mycophagous mammals disperse beneficial fungi (e.g. mycorrhizae) and their diggings can create suitable sites for microbial growth (Fig. 1). Mammal diggings therefore increase plant vigour and resilience, increase biodiversity, and consequently improve ecosystem functioning (*Fleming *et al.*, 2014; *Moore *et al.*, 2014).

We are currently managing ecosystems that have undergone a massive loss of ecosystem processes over the last ~200 years. Despite once being described as common, around half of digging mammal species are now extinct or under conservation threat, and the majority of extant species have undergone marked range contractions (*Fleming et al. 2014). The loss of digging mammals from our landscapes can lead to untold outcomes in the future (e.g. *Murphy et al. 2015). It is quite likely that the effects of lost tree recruitment have yet to be felt for many systems. For example, without digging mammals to break up the hydrophobic surface crust of the soil and create a heterogeneous surface, plant seeds are more likely to fall prey to seed predators and are less likely to find suitable sites for germination, leading to reduced recruitment (Newell 2008). Additionally, established trees may already have hypogeous mycorrhizal associations to supply their essential nutrients (Fig. 1), but the same is not true for new plants recruited in the absence of animals that spread the spores of these fungi.

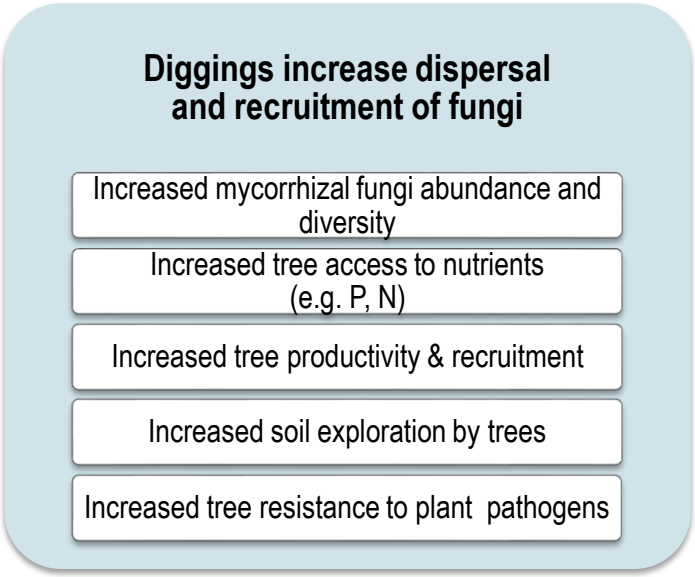

Fig. 1. *Mycorrhizal fungi contribute to increased plant growth, health, and resistance to disease (*Fleming et al. 2014).*

Southern brown bandicoots are one of the only digging mammal species that have remained reasonably abundant across Australia. As ecosystem engineers, they manipulate and move soil using their strong forefeet and claws (biopedturbation) as they forage for mycorrhizal fungi, invertebrates, tubers and seeds. **The subspecies in southwest WA ('quenda') play a critical role in ecosystem regulation**; an individual quenda can create

up to 45 pits and displace ~10 kg soil/day (up to 3.9 tonnes soil/year) (*Valentine et al. 2013). In addition to their ecosystem services, the presence of bandicoots enhances the quality of our lives in cities (Dowle and Deane 2009). A 2012 Community Quenda Survey (carried out by Dept. Parks & Wildlife and WWF Australia) reported high public interest in these bandicoots across Perth, with the species being surprisingly well-known and almost universally well-liked (Howard et al. 2014). Similarly, 85% of Brisbane residents indicated they were or would be pleased to know that bandicoots survived near them (FitzGibbon and Jones 2006).

SIGNIFICANCE AND INNOVATION: *This project addresses an important problem for the industry partners because* **habitat availability for quenda is decreasing daily, and connecting and enhancing bushland remnants can increase their functional role for biodiversity conservation.** Quenda are regularly trapped and relocated to make way for ongoing housing development that invariably means loss of fauna habitat. City councils need to approve clearing for developments, but also need to identify suitable bushland translocation sites, and the presence of quenda is strongly correlated with the amount of native vegetation present (Howard et al. 2014). Together with City of Mandurah, we have identified which of their 106 reserves are currently being used by quenda, and which ones would be suitable for future translocations (*Bryant et al. unpublished data). Managing these animals at the metapopulation level, enabling movement that could preserve long-term genetic viability of populations through underpasses and vegetation corridors, can ensure the future for these animals. Even small populations can be viable, if they are embedded in a permeable landscape that offers opportunities for individuals to move between seasonally available resources and for genetic mixing. Improving quenda habitat structure, connectivity and availability, and identifying threats to quenda in urban areas, will help achieve this conservation outcome.

This project meets the objectives of the Linkage Projects scheme in five ways:

(a) Engaging with community for environmental and human health outcomes. Enhancing natural spaces within cities is an important part of creating healthy environments for communities living in cities.

(b) Engaging with citizen science is a powerful way to increase research capacity, especially for basic biological studies (Coulson et al. 2014; Mulder et al. 2010), and also has the benefit of increasing awareness of Australian fauna and importance of conservation action (Tulloch et al. 2013). In a survey of Sydney residents, Dowle and Deane (2009) found that two-thirds of 177 respondents correctly indicated that bandicoots were a native animal, but 5% indicated that they were 'feral', and 33% of residents perceived bandicoots as a pest because they leave diggings in the garden (64%) or they carry ticks (44%). Residents are unlikely to protect native species in their backyards unless they understand and feel some affiliation with them. Murdoch University (MU) researchers have been working closely with Mandurah over the last 3 years to identify where quenda persist within the urban matrix, and quantify and understand their vital role in ecosystem health. Building these results into future management actions with community involvement will serve to build awareness that can turn negative opinion into ownership and custodianship, increase conservation action, and add quality to our lives (Fig. 2).

(c) The project contributes to *Living in a Changing Environment* by **developing novel tools for future management of urban bushland reserves**. We will develop and enhance existing relationships into a long-term strategic research alliance between Mandurah residents, City Council, and researchers, to deliver state-of-the-art research that will be incorporated into land management policy and practice.

(d) We will undertake internationally competitive research through a transdisciplinary approach (genomic, ecological, sociological), connecting and enhancing bushland remnants to increase their functional role. Data will be published in international peer-reviewed journals.

(e) This project develops capacity through strengthening collaborations and research training. We will leverage and value-add to existing resources of the partner organisation, and provide training for a research associate and PhD student in the areas of genomics and behavioural ecology.

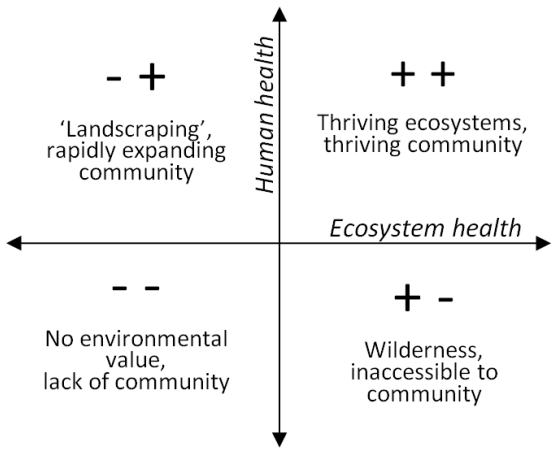

Fig. 2. *Engaging with community for conservation outcomes not only improves ecosystem function, but also gives back to the community by improving human health outcomes.*

This project will advance our knowledge base by **establishing long-term data collection needed for informed management in the face of a rapidly changing environment. Long-term data sets are powerful indicators of potential threats, and continuous data collection will allow us to study long-term changes in relative abundance and activity patterns of quenda as environmental sentinels.** There have been a number of surveys of the occurrence and distribution of bandicoots in

urban areas across Australia, but as far as we are aware, bandicoots are not currently part of any large-scale social media or citizen science project. Comparison of 1993 and 2012 Community Quenda Survey data identified locations where quenda decreased (or increased) in abundance over time (Howard et al. 2014). Building on these existing survey data (Howard et al. 2014), we will work with a range of partners to develop survey tools (e.g. for inclusion in ClimateWatch; http://www.climatewatch.org.au/) to establish continuing data collection for quenda, including 'capture locations' of sightings, relative size of animals, types of habitat used, mortalities and perceived threats, and activity patterns. We will then engage with community groups to increase uptake of these tools.

*This project will provide significant **environmental, social, and economic benefits**:*

(a) Ecosystem health in a changing environment - enhance & reconnect

- tree recruitment and plant growth
- maintain ecosystem functions
- biodiversity
- environmental sentinels for the future

(b) Community health and wellbeing - engage & contribute

- sense of place, aestetics and amenity values
- naturalness and reconnection
- visitation and involvement
- community access and activity
- human wellbeing

(c) Productivity and economic growth - grow & share

- enhance commercial & residential development
- increased property values
- community contributes to urban bushland upkeep
- increased tourism
- reduced health costs

*and fits within **three of the ARC's Science and Research Priority Areas**:*

(a) Environmental change: We will contribute towards *living in a changing environment* by increasing tree recruitment and plant growth, maintaining ecosystem function and linkages, increasing biodiversity, and building data on quenda as environmental sentinels for the future. Most of our new housing developments remove all vegetation back to bare sand (biodiversity annihilation or 'landscraping') before building houses (Fig. 2); consequently re-building any environmental values requires significant investment and planning. Maintaining connected patches of natural habitat within these landscapes can aid recolonisation with birds, insects and mammals like the quenda.

(b) Human health: Healthy ecosystems significantly contribute to *human population health and wellbeing*, giving a sense of place, increasing aesthetics and amenity values, improving naturalness and nature reconnection, increasing visitation, involvement, community access, activity and therefore human wellbeing. Studies document marked declines in the time that children spend outdoors (Wen et al. 2009), with rising levels of childhood obesity, attention deficit disorder, and youth drug abuse. Although the root causes of these problems are multifaceted, Louv (2008) argues that these symptoms represent the human costs of alienation from the natural world, a phenomenon he described as *'Nature Deficit Disorder'*. In addition to the lure of the TV and computer, a lack of parks and natural surroundings in bleak urban landscapes are important reasons why children spend more time indoors.

(c) Soil & water: Project goals will contribute towards enhanced commercial and residential development, increased community contribution to upkeep of urban bushland, and increased tourism, thereby lifting productivity and economic growth. Desired outcomes will aim to minimise damage to, and develop solutions for restoration and remediation of urban systems, and will lead to better decision-making strategies in the context of potentially conflicting demands between development, the environment, and landscape management.

APPROACH AND TRAINING: *The project's aims and concepts are novel and innovative* because we will be combining three complementary fields of research (Molecular Biology, Behavioural Ecology, and Education for Sustainability) to identify how quenda contribute to healthy urban bushland. Information obtained through this research will increase understanding of the ecology and conservation efforts of quenda, as well as helping Mandurah to identify and suggest management options of reserves to maintain and encourage quenda populations to thrive in the face of current and future urbanisation pressure. Social science and education are *embedded* within each of the three scientific research projects (below), demonstrating a truly transdisciplinary approach.

We will use the quenda to engage urban residents with their local bushland environment: Mandurah currently runs 15 community plantings and 10 school plantings each year (every weekend over winter). We will advertise, using the charismatic urban quenda as a tool to attract participants to these planting events, then disseminate information about urban quenda and promote the associated citizen science opportunities.

We will increase community awareness and engagement with urban bushland conservation: We will not adopt a prescriptive education method for engaging with community, but rather rely on community feedback after initial workshops and consultation opportunity. We will coordinate initial training workshops on methods for identifying quenda diggings/scats and methods for data collection, and will develop further workshops (e.g. how to develop a

quenda-friendly garden) based on need and desire as determined by community consultation.

We will initiate citizen science action to contribute to long-term conservation actions: Citizen science and ecological observations both have strengths and limitations, but combining these sources can provide a powerful approach to data collection (*Bartholomaeus 2015). If projects are well designed, the tasks realistic and effectively managed, and volunteer level of experience is taken into consideration, citizen science projects can be immensely valuable (Foster-Smith and Evans 2003; Newman et al. 2003). Incorporating citizen science can also help provide information that researchers would not otherwise be able to access; in this case, records of quendas accessing backyards would not be possible without working directly with the respective landholders, while tracking domestic cats requires their owners are on board with the project. We will use the methodology that has been applied successfully by the Australian Association for Environmental Education (AAEE WA) for the TurtleWatch program (*Lewis and Baudains 2015), combining citizen science observations and field data collection to establish long-term monitoring of urban quenda. This integrated engagement strategy will be evaluated through the implementation of a pre-participation benchmark survey and a follow up post-participation survey to identify the impact of citizen science and interaction with the urban quenda as a tool for community engagement and education. The inclusion of this evaluation will provide critical insight into the benefits and limitations of this engagement approach.

Community engagement: We will work together with the Mandurah City community (working with 10 'friends of' groups, several schools, and engaging with citizens through a 'Quenda App', signage, blog site) on **three projects:**

PROJECT 1. Identify how quenda contribute to healthy urban bushland through dispersal of mycorrhizal fungi – *led by CIs Hardy, Baudains, Fleming and Research Associate (RA)*

✓ indicates extension of pilot data

Aim		Actions		Outcomes (Scientific, Community, Management)
1. Ecosystem health	(1a)	**Inoculations:** Identify differences in mycorrhizal community between habitat patches	✓**S**	Quantify role for quenda moving mycorrhizal across the landscape
		Quenda scats collection and plant inoculation	**M**	Improved seedling growth and survival
RA	(1b)	**Enhancement:** Identify quenda food and shelter plants	**SM**	Improved enhancement of existing habitat; Targeted improvements for restoration
	(1a) & (1b)	Plantings	**SC**	Measurable increase in urban habitat for quenda
		Monitor plant growth	**S**	Quantify role of quenda in vegetation health
		Engage citizen science (ClimateWatch; CW)	**SCM**	Establish long-term monitoring

(1a) 'Quenda inoculated' plants: We will trial novel and innovative approaches for improving plant health, testing effects of inoculation of seedlings. *Eucalyptus gomphacephala* (tuart) has undergone a significant decline since the early 1990s, throughout its distribution along the coastal dune belts of the Swan Coastal Plain, WA. The greatest decline has occurred in the woodlands around the Mandurah area, where tuarts are the dominant keystone species and many tuart of all age classes have died (*Cai et al. 2010; Edwards 2004). There is a strong correlation between mycorrhizal root associations and signs of tuart tree crown health (r^2_{16}=0.75) (*Scott et al. 2013), suggesting a link between the decline and absence of ectomycorrhizae (*Ishaq et al. 2013; *Scott et al. 2013).

In the absence of bandicoots in isolated and altered habitats, 'inoculating' plants with bandicoot scats could serve to artificially increase mycorrhizal associations. For some fungi, passing through the gut of an animal can break spore dormancy, leading to increased germination rates (Lamont et al. 1985; Reddell et al. 1997). This may explain why directly inoculating seeds with mycorrhizal fungal inoculum sometimes has no effect on eucalypt seedling establishment and growth (So et al. 2011), while inoculation using mycophagous marsupial scat can enhance seedling growth (Claridge and May 1994; Lamont et al. 1985). Our pilot data indicate that inoculating *E. gomphacephala* seedlings with bandicoot scats significantly increases plant-mycorrhizal associations compared with negative controls (χ^2 = 15.57, p = 0.001).

As a first step, we will identify where to source quenda scats from. High Throughput Sequencing (HTS) of a small pilot sample revealed significant differences in the mycorrhizal fungi community evident in quenda scats for samples collected from forest, woodland, and coastal heath habitat types. We will therefore use HTS of quenda scats from across a broad range to sites to identify the best locations (most

Fig. 3. Plant labels for seedling trials.

diverse mycorrhizal fungi community) to derive source material for inoculations. We will then inoculate nursery seedlings with bandicoot scats for extensive plantings, and monitor their recruitment success and growth over time.

(1b) 'Quenda endorsed' plants: Shelter and food are key habitat resources for animals (e.g. *Dundas et al. 2013; *Poole et al. 2014; *Valentine et al. 2014). We will identify shelter plants through tracking animals (**Project 2a**) and food sources used by quenda through HTS analyses (**Project 2b**), to target urban plantings for quenda habitat.

Community engagement: working with researchers to trap animals, collect bandicoot scats, large-scale seedling inoculation and cultivation, coordinated plantings and monitoring. Using 'quenda endorsed' food and habitat plants, and 'quenda inoculated' seedlings (Fig. 3) will serve to capture the imagination of community, and link their voluntary actions with a charismatic flagship urban mammal.

PROJECT 2. Identify habitat use by quenda, using GPS technology to track and monitor animals –
led by CIs Hardy, Baudains, Fleming and Research Associate (RA)

✓ Indicates extension of pilot data

Aim		Actions		Outcomes (Scientific, Community, Management)
2. Habitat use by quenda	**(2a)**	**Space use:** Identify reserves used by quenda	✓ **SM**	Establish factors correlated with presence of quenda
		Tracking to identify quenda habitat selection	**SCM**	Identify food and refuge species for plantings; Identify key habitat for conservation management actions
	(2b)	**Diet:** Identify quenda diet	**SM**	Enhancement of existing habitat; Targeted plantings for restoration
	(2a) & (2b)	Develop community engagement strategies	**CM**	Increase awareness of quenda across communities; ownership of and affiliation with local quenda populations
		Develop environment sustainability outcomes	**C**	Increase awareness in schools; Develop ownership of and affiliation with local quenda ('backyard bandicoots')
RA		Report quenda sightings (CW) of 'backyard bandicoots'	**S**	Establish continuous long-term data collection (CW)

(2a) Space use: We will trap and track quenda to identify use of corridors and habitat selectivity. We aim to track a minimum of 30 individual quenda using high-resolution (short time interval) GPS technology (further detail F1-2a) to identify corridors (connectivity of native vegetation reserves) and plant species used for refuge. Data will be analysed using GIS tools to identify corridors used to access urban bushland reserves, compare locations with available vegetation to determine selection/avoidance (e.g. *Poole et al. 2014), correlate space use patterns with landscape features (e.g. distance to nearest road, density of housing, extent of native vegetation remaining), and identify key plant resources used by the animals (diurnal rest sites). Dynamic tracking information will be disseminated through a website, capturing locations of GPS-tracked animals. A blog website interface will facilitate community contributions, while citizen science will be developed through collection of sightings via a 'Quenda App' (Gaia Environmental Consultants); sightings will be analysed for spatial/temporal patterns of presence data.

(2b) Diet: Scats collected from trapped animals (using slightly raised cage traps) will be analysed using HTS for diet items: ectomycorrhizal fungi, plants and invertebrates (Zeale *et al.* 2011; Ihrmark *et al.* 2012; Lindahl *et al.* 2013; Burgar *et al.* 2014). Briefly, scats will be air-dried, crushed to a fine powder, DNA extracted and HTS carried out to determine dietary composition (further detail F1-3a). Sampling across the year will contribute important seasonal diet data, and we therefore anticipate analysing ~240 scat samples.

Community engagement: animal tracking, local school students and landholders collect records of diggings in their backyards (via Quenda App and ClimateWatch), residents use IR camera traps to record what is present in their own backyards. Developing interactive web interfaces will encourage contribution and interest in the data collection. These initiatives will establish methods for long-term data collection.

PROJECT 3. Identify and mitigate threats to quenda
– led by CI Fleming and PhD student (PhD)

Aim		Actions		Outcomes (Scientific, Community, Management)
3. Identify and mitigate threats	**(3a)**	**Roads:** Collate information on quenda mortalities (CW, tracking)	**M**	Identify high risk road areas and mitigation strategies Redirecting quenda from dangerous road locations
			M	Quantifying barriers to quenda movements
PhD	**(3b)**	**Predation:** Tracking predators to identify space use and efficacy of semi-permeable reserve fencing	**SM**	Quantifying barriers to predator movements
			CM	Identify optimal fencing structure
		Monitoring to identify predator use of reserves	**SM**	Identify relative risk between reserves

(3a) Roads: Of 378 mortality events reported under the 2012 Community Quenda Survey, vehicle strike accounted for 44% of deaths (Howard et al. 2014). Vegetated road reserves and cycle paths provide quendas with refuge habitat, and also enable them to move between habitat patches and to access suburban gardens; however, quendas living alongside busy roads are at risk from vehicle strike. Identifying key habitat resources by tracking ~30 individuals (**Project 2a**) will enable us to locate road 'black spots', sites that could be reconstructed to include wider verges, impermeable fencing, or underpasses to reduce likelihood of animals crossing roads. Additionally, we will collate information on quenda mortalities through citizen science.

(3b) Predation (PhD project)**:** In the 2012 Community Quenda Survey, predation accounted for 30% of reported quenda deaths, the majority due to introduced mammals (cats, dogs or foxes) (Howard et al. 2014). Understanding the movement of foxes may indicate road/vegetation factors that influence their movement (Saunders and Hobbs 1991; Simberloff and Cox 1987). We will track 7 foxes using GPS collars (Telemetry Solutions; further detail F1-2b). We will also track domestic cats, using small rechargeable GPS devices (CatTrack 1; further detail F1-2c) that can be deployed by cat owners, increasing community involvement in data collection. We will analyse preferred pathways through the urban landscape, sites that are avoided, and will specifically interrogate data to reveal whether semi-permeable fencing currently used by Mandurah is successful in keeping out potential predators. Tracking will be supported by deploying 30 IR camera traps (Reconyx HC500; F2-2a) within bushland reserves to identify use by predators (and quenda).

Community engagement: record predator presence, contribute to tracking methods, track domestic cats, use IR camera traps to record predators present in local bushland and backyards. Signage (Mandurah contribution; F2-6a) will be targeted around identified 'black spots' as part of increasing community awareness.

PROJECT RESEARCH ENVIRONMENT: Murdoch University (administering organisation) is research-led and ranks in the top 350 universities worldwide (THE 2014). MU has a strong existing research environment of direct relevance to this project, bringing together outstanding ecologists, biological scientists, biotechnologists and education specialists to create the capacity to tackle environmental sustainability challenges now and into the future. There is a supportive university, school, and research group environment, and this project has direct alignment with work currently carried out at MU. The CIs are based in the School of Veterinary & Life Sciences (VLS), the 'research hub' of MU, where a vibrant research community (130 research staff and 300 PhD students) are available to contribute expertise where and when required. VLS has an annual category 1 research income of 25 million, with 5 new ARC-Linkage projects awarded in 2015 alone. The Environment is one of three central areas of research focus within VLS (along with Animal and Human Health and Primary Production), taking a central role in our integrated environmental research and teaching. With research strengths (ERA 2012 rankings) in Zoology (4), Genetics (4), Environmental Science and Management (4), Ecology (3), and Plant Biology (3), the collaborative research environment provides a wealth of opportunities at the interface between disciplines. Under 'Environment', this research fits squarely into two of the six research themes of VLS; namely **'Wildlife Biology & Conservation'** (www.murdoch.edu.au/School-of-Veterinary-and-Life-Sciences/Our-research/Wildlife-Biology-and-Conservation/), and **'Ecology, People & Environment'** (www.murdoch.edu.au/School-of-Veterinary-and-Life-Sciences/Our-research/Ecology-People-and-Environment/). In these two research themes, there are 10 Professors, 8 Associate Professors, 26 Senior Lecturers and Lecturers, along with 18 Research Fellows (including 3 DECRAs S Godfrey, A Gleiss, W Xu) and over 100 PhD students. Of direct relevance for this project, we have internationally-recognised strengths in Plant Pathology and Wildlife Biology, with large cohesive research programs in these fields that directly complement our translational research in Policy Development and Education for Sustainability.

VLS researchers (e.g. CIs as well as U Ryan Scopus 'h'=47 LP130100050; RCA Thompson 'h'=56; K Warren 'h'=12) have been studying bandicoots over the past decade (quenda and other species), with a solid research base on these animals. This research has quantified the role of quenda as ecosystem engineers, (*Valentine et al. 2013), captured their role in litter turnover, nutrient cycling, soil water penetration, seedling recruitment, and plant growth (*Fleming et al. 2014), described anatomical adaptations to digging (Warburton et al. 2014; 2015), or examined clinical disease and parasite transmission (e.g. Appelbee et al. 2005; Bennett et al. 2008; Chen et al. 2011; Thompson et al. 2008; Wicks and Clark 2005).

CIs Fleming, Hardy, and Baudains have a strong track record of collaboration. CIs Fleming and Hardy have published 15 papers together. CIs Fleming and Baudains work together on a recently-awarded project examining factors influencing uptake of canid control methods under agricultural landscapes. All three CIs collaborated under the WA State Government-funded Centre of Excellence (CoE) for Climate Change, Woodland and Forest Health, which was awarded two small grants that supported preliminary data collection contributing to the current proposal:

- 3 years funding from City of Mandurah 2013-2015 ($45,000) to identify the Role of Australian digging mammals in ecosystem health, collating knowledge regarding the role of digging mammals as drivers of ecosystem processes and change (*Fleming et al. 2014; *Valentine et al. 2013), surveying reserves across the City of Mandurah in terms of evidence of bandicoot activities, and identify the potential for reintroduction of digging mammals to assist restoration of degraded systems (unpublished data).
- MU Small Grant in 2015 ($15,000) supported field studies to identify the role of bandicoot diggings on plant growth (unpublished data), and HTS analyses of quenda scats (unpublished data).

PARTNER ORGANISATION COMMITMENT AND COLLABORATION: The City of Mandurah spends a good proportion of its annual budget on actions that empower the community to play an active role in environmental protection and restoration. For example, Mandurah and MU researchers are collaborating on a current ARC Linkage project (LP150100451), they have been Industry Partners on two previous ARC Linkage Projects (LP0346931 and LP0668195), and were financial contributors to the CoE (more detail in D3). Community perceptions surveys indicate that Mandurah residents value their environment as their highest priority. Developing a better understanding of quenda will potentially help to design better rehabilitation and management plans, involve community in stimulating and meaningful environmental activities, and give more purpose to the retention of urban bushland reserves, corridors, and in particular the Mandurah Bushland Buyback Scheme. This project will:

- **Build community awareness and engagement that contributes to long-term conservation actions.** Developing 'friends of' action groups will provide a forum where community members can become engaged in flora/fauna monitoring and assisting in revegetation and rehabilitation of local bushland areas. This work will actively contribute towards building healthy, supportive community groups that value urban bushland places as part of their urban landscape. Individual community members can participate and volunteer in these actions, and by doing so may increase their mental health values. Mandurah City Council look forward to being able to report on community benefit as well as the ecological benefit of their management actions.
- **Increase community awareness and engagement that contributes to long-term conservation actions**. Supporting the development of school and community engagement initiatives will reconnect students and landholders with their local natural environment (including their own backyards). This citizen science approach will expand outreach to the broader community to promote conservation of quenda and it will substantially contribute to management change, delivering science through existing networks.

ROLE OF PERSONNEL: We have brought together a very strong research team with complementary skills and experience to complete this project. The CIs and PI will jointly share project IP and be responsible for the overall direction of the project, and will work closely with the Research Associate and PhD students to ensure objectives are met. All three CIs are on 20:40:40 service/teaching/research roles; CI Baudains is employed part-time (0.6FTE).

- **CI FLEMING (0.2FTE)** leads the western Wildlife Ecology and Behaviour (WEB) research group at MU (www.westernWEB.net). She will be involved in all aspects of the project, working with the PI and CIs to ensure integration and synthesis of this research. CI Fleming will co-supervise the PhD student and the Research Associate, play a lead role in the design and execution of this project, contribute to data analysis/interpretation, and development of communications.
- **CI HARDY (0.1 FTE)** is a plant pathologist with a wealth of expertise in broad-scale ecological studies such as this one. CI Hardy will provide expertise on tree health, assistance in the mycorrhizal trials, and co-supervision of the Research Associate. He will liaise with stakeholder groups to communicate the findings of the research. LP120200581 finishes mid-2015, leaving three current LP grants active; consequently CI Hardy will have the time and capacity to contribute to the current project, based on his current 0.6FTE for research.
- **CI BAUDAINS (0.1FTE)** is a social scientist with a background working in Education for Sustainability and extensive experience with the conduct of mixed-methods interdisciplinary research. CI Baudains' track record in Education for Sustainability outcomes highlights the value and importance of her translational outputs. CI Baudains will contribute to the design and analysis of the social engagement instruments, will provide educational expertise, co-supervise the Research Associate and PhD student, and liaise with stakeholder groups to communicate findings of the research.
- The **Research Associate (1FTE)** will be responsible for coordinating voluntary contributions (e.g. inoculation trials, planting days, seedling monitoring) and carrying out the quenda trapping and tracking studies. The **PhD student (1FTE)** will carry out the tracking of fox and domestic cat tracking through the urban matrix. We will advertise broadly within Australia for these two positions.

MANAGEMENT OF DATA: We will communicate scientific, community and management outcomes of this study:

- **Scientific** outcomes will be made available through publication in international peer-reviewed journal articles with raw data made available on our research website www.westernWEB.net. Publications will target Education for Sustainability, Ecology, and applied sciences journals. Results will be also be communicated via oral presentations, and research findings bulletins (www.murdoch.edu.au/School-of-Veterinary-and-Life-Sciences/Our-research/Our-Bulletins/).
- **Community** education events (field days, workshops) will serve a double purpose of data dissemination and engagement of community and networks with the data collection and conservation actions. We will work with ClimateWatch to capture citizen science data on urban bandicoots across Australia; this continuing data collection will establish a national long-term data collection method to inform future needs and will be available upon request to ClimateWatch beyond the life of this project.
- **Management** outcomes will be developed in collaboration with our industry partners, and will include methods for ecosystem enhancement, development of public information, and contribution to on ground management applications. Management outcomes will be directly implemented through community and City Council actions.

We will establish a Backyard Bandicoot reference group to ensure that we meet quarterly. Mandurah is willing to provide officer support for the functioning of such a group. Mandurah will promote the project and disseminate outcomes through social media, media release, and signage. MU also recognises the value of disseminating research results in a range of ways that are considered appropriate to the project. A communications team is available to prepare media releases to report results of general interest to the public through main stream media outlets. Research outcomes will also be disseminated by MU via web pages and by its media public relations arm.

We will also develop a 'Quenda App' (linked from signage and advertising via a QR code) that can collect sightings of animals and diggings for spatial analyses, and will also provide information about the project and about these bandicoots (what they look like, what they do, why they are important, what scats look like, what digs look like, what types of habitat they require, what eats them and so on). We have experience with developing apps for Citizen Science (e.g. the marri app www.emrc.org.au/the-marri-app.html; coastal walkabout) and believe that they can contribute profitably to the 'Backyard Bandicoot' project.

As researchers, we also have an active research blog site (www.westernWEB.net), twitter feed (@western_web), and two facebook sites (westernWEB volunteer experience and Behavioural Ecology and Evolutionary Research Society (BEERS) – journal club) that will be used to disseminate information and engage with our followers. We will have an active feed of photos, tracking quenda location data and outcomes as they develop.

REFERENCES

Appelbee, et al. 2005. *Trends in Parasitology* 21:370-6. ***Bartholomaeus**. 2015. Understanding the decline of urban wildlife: the critical role of combining ecological and social research to define solutions, Murdoch University WA. **Bennett, et al.** 2008. *Virology* 376:173-82. **Burgar, et al.** 2014. *Mol Ecol* 23:3605-17. ***Cai, et al.** 2010. *Forest Ecology and Management* 260:1047-57. **Chen, et al.** 2011. *Journal of Virology* 85:4487-500. **Claridge & May**. 1994. *Aust J Ecol* 19:251-75. **Coulson, et al.** 2014. *Animals* 4:272-91. **Davidson, et al.** 2012. *Frontiers in Ecology and the Environment* 10:477-86. **Dowle & Deane**. 2009. *European Journal of Wildlife Research* 55:45-52. ***Dundas, et al.** 2013. *Aust Mammal* 35:166-74. **Edwards**. 2004. Environmental correlates and associations of tuart (*Eucalyptus gomphocephala*) decline. Masters Thesis, Edith Cowen University. **Eldridge, et al.** 2012. *Geomorphology* 157-158:131-41. **FitzGibbon & Jones**. 2006. *Wildl Res* 33:233-41. ***Fleming, et al.** 2014. *Mammal Rev* 44:94-108. **Foster-Smith & Evans**. 2003. *Biol Conserv* 113:199-213. * **Garkaklis, et al.** 2004. *J Arid Environs* 56:569-78. **Howard, et al.** 2014. Community Quenda Survey 2012. WWFAustralia, Perth, WA.: WWF-Australia and the Department of Parks and Wildlife, Western Australia. **Ihrmark, et al.** 2012. *FEMS Microbiology Ecology* 82:666-77. ***Ishaq, et al.** 2013. *Mycorrhiza* 23:359-71. **Lamont, et al.** 1985. *New Phytologist* 101:651-6. ***Lewis & Baudains**. 2015. *Open Review of Educational Research* 2:167-81. **Lindahl, et al.** 2013. *New Phytologist* 199:288-99. **Louv**. 2008. *Last child in the woods: Saving our children from nature-deficit disorder*: Algonquin Books. ***Moore, et al.** 2014. *Aust Mammal* 36:146-53. **Mulder, et al.** 2010. *Wildl Res* 37:440-6. ***Murphy, et al.** 2015. *Pacific Conservation Biology* 21:243-52. **Newell**. 2008. The role of the reintroduction of greater bilbies (*Macrotis lagotis*) and burrowing bettongs (*Bettongia lesueur*) in the ecological restoration of an arid ecosystem: foraging diggings, diet and soil seed banks. PhD thesis, University of Adelaide. **Newman, et al.** 2003. *Biol Conserv* 113:189-97. ***Poole, et al.** 2014. *Wildl Res* 41:510-21. **Reddell, et al.** 1997. *Biotropica* 29:184-92. **Saunders & Hobbs**. 1991. *Nature Conservation 2, The Role of Corridors*. Chipping Norton, Australia: Surrey Beatty. **Scott, et al.** 2013. *Australasian Plant Pathology* 42:121-31. **Simberloff & Cox**. 1987. *Conserv Biol* 1:63-71. **So, et al.** 2011. *Ecological Management & Restoration* 12:157-60. **Thompson, et al.** 2008. *Experimental Parasitology* 120:88-93. **Tulloch, et al.** 2013. *Biological Conservation* 165:128-38. ***Valentine, et al.** 2013. *Aust J Zool* 60:419-23. ***Valentine, et al.** 2014. *Biological Conservation* 175:1-9. **Warburton, et al.** 2015. *Aust J Zool* 63:147-62. **Warburton, et al.** 2014. *Aust J Zool* 61:402-19. **Wen, et al.** 2009. *International Journal of Behavioral Nutrition and Physical Activity* 6:15. **Wicks & Clark**. 2005. *Comparative Clinical Pathology* 14:56-60. **Zeale, et al.** 2011. *Molecular Ecology Resources* 11:236-44.