Threatened Species Research Forum

Western Australian Ecology Centre

9th July 2010

A Review of WA Government Research into Threatened Species

Collaborative partners

Front cover images: (left) The DRF *Darwinia masonii* restricted to Mt Gibson Ranges, WA (Photo: Ben Miller) and (right) the endangered *Geocrinia alba* in a breeding burrow (Photo: Grant Wardell Johnson).

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That Feral Cat Bait

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Predation by feral cats is recognized as a significant threat to fauna conservation in Australia. Not only do feral cats prey on native fauna and have the potential to spread diseases but also they have proven to be an obstacle to fauna reintroduction programs. As a consequence of these impacts, a feral cat control research program was initiated by the Western Australian Department of Environment and Conservation (DEC) under the umbrella program "Western Shield". Baiting is recognised as the most effective method for controlling feral cats when there is no risk posed to non-target species.

Prior to commencement of this research, baiting programs for feral cats had been ineffective principally because baits used were for other introduced predators such as foxes and wild dogs and were unattractive to cats. DEC researchers conducted an extensive series of trials in an endeavour to develop a bait medium that was palatable to feral cats and capable of carrying a toxin. The baits had to be relatively easily and cheaply manufactured and would stay intact when distributed from an aircraft over broad-scale areas. These trials have led to the development of the feral cat bait known as '*Eradicat*®'.

Baiting campaigns using *Eradicat*® have proven to be an effective method in reducing feral cat numbers and it is now used as a control tool for feral cat management at a number of mainland sites in arid and semi-arid regions. A recent project has gone a long way to demonstrating that the sustained control of introduced predators (both feral cats and foxes) in the southern rangelands can also be achieved using this bait. Baiting campaigns using *Eradicat*® have also been used effectively to eradicate feral cats from several islands, including Hermite Island in the Montebellos and Faure Island in Shark Bay. Following feral cat eradication successful translocation of a number of native species to these islands has occurred. A feral cat eradication campaign is being planned for Dirk Hartog Island, the largest island off the Western Australian coast. The Dirk Hartog project would become the largest feral cat eradication campaign attempted on an island globally. The island could potentially support one of the most diverse native mammal assemblages in Australia following successful eradication of feral cats and contribute significantly to the long-term conservation of several threatened species.

If further fauna declines are to be averted and re-introductions are to succeed, integrated management programs, which address threats, must be implemented. Effective control strategies for feral cats must be an integral component of these management programs. DEC researchers are developing feral cat control techniques and strategies that address these concerns.

Protection of Threatened Flora by Phosphite application in Southern Western Australia

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Phytophthora cinnamomi is a primary threatening process for threatened flora in southern Western Australia. This is particularly so in the Stirling Range (SRNP) and the Albany coastal area where disease impact is high due to susceptible plant communities and conducive topography, soils and climate. Several highly susceptible Threatened Flora species in the SRNP and Albany area have already undergone population extinctions and are at very high risk of species extinction (Barrett *et al*. 2008). New infestations continue to manifest themselves in formerly healthy populations through either animal or human vectoring, particularly after disturbance by fire. Since 1997, the fungicide phosphite has been used as a low volume aerial application to enhance the survival of threatened flora that persist in dieback infested areas or to slow the spread of the disease into healthy populations. The program has expanded gradually from 1997 and currently some 26 threatened flora are sprayed comprising an area of approximately 350 ha. Experimental sites have been set up to assess the efficacy of the programs. Results generally indicate that survival of threatened flora is increased with phosphate applications with Critically Endangered species such as *Banksia anatona Daviesia glosso*s*ema*, and *Daviesia pseudaphylla* showing significantly reduced mortality. However, in other species such as *Banksia montana* control seems to be having little effect and *ex situ* conservation efforts have needing to be fast tracked. Despite the lack of control in *B. montana* monitoring of survival rates has shown phosphite to be an effective short to medium term tool in slowing decline in many threatened species. The phosphate application program has effectively 'bought time' to allow seed and other germplasm to be collected from highly threatened populations and translocations or 'seed orchards' to be implemented at disease-free sites. *Aus J Bot,* **56**:1-10.

Carnaby's Black Cockatoo night roost surveys in the Perth region

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Carnaby's Black-cockatoos (*Calyptorhynchus latirostris*) are a threatened species that is endemic to Western Australia and under serious threat from habitat loss. Each year many birds migrate to the Swan Coastal Plain over the non-breeding summer period where they become a highly visible and iconic part of the Perth environment. A survey of Carnaby's Cockatoos by Birds Australia in 2006, identified 16 night roosts and showed that at least 4,510 birds visit the greater Perth region. This first Great Cocky Count also identified night roost counts as the most accurate way to estimate the number of birds and monitor changes over time. Subsequent surveys by DEC volunteers in 2008 and 2009 identified 70 known or likely roost sites, and in 2010 DEC joined with Birds Australia to repeat the 2006 Great Cocky Count.

During the 2010 Great Cocky Count on April 7th, 350 volunteers completed 189 surveys across 223 sites in the greater Perth Region. An estimated 6,600 birds occurred across 130 night roost sites (excluding 80% of the 2,123 birds recorded in the Perth Hills roosts that were thought to be Baudin's Black-cockatoos). The16 roost sites surveyed in 2006 were compared with 47 sites that occurred within 2.5 km of these sites, and found no significant difference in the number of Carnaby's Cockatoos between the two survey periods ($p=0.9$, $df=13$). However, the average number of birds per roost was lower in 2010 (220 ± 54 compared with 322 ± 135 in 2006), as was the total number of birds estimated for the Greater Perth region (3,084 in 2010 compared with 4,510 in 2006).

A typical night roost site has tall, dense canopied trees, close to water where the birds can drink and close to food trees such as banksias, bottlebrush and Marri. The roost trees are usually clumped and at larger roosts, cover an area of at least five hectares. Maps showing the pattern of use of trees at a large, permanent roost in Bentley will be shown to demonstrate the shifting nature of roost sites. Monthly roost counts with volunteers are currently underway and will be repeated in subsequent years as a means to accurately monitor population changes. The proportion of single birds to pairs to triplets, flying into the night roosts, is also recorded as a measure of breeding success.

Conservation of Graceful Sun-Moth Habitat

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The graceful sun-moth (GSM) is a small day-flying moth endemic to south-western Australia, and is restricted, predominantly, to the Swan Coastal Plain between Jurien Bay in the north and Preston Beach in the south. There are two apparently disjunct, outlying populations at the north and south extremities of the range: a population near Leeman, on the Geraldton Sandplains, 50 km north of the Jurien Bay townsite; and at Binningup, 30km south of Preston Beach.

Records for the GSM show that its distribution has declined significantly as a result of habitat loss for housing, industry and agriculture. The largest loss of habitat has been due to urbanization in the greater Perth area (Yanchep – Fremantle – Mandurah), resulting in severe fragmentation of the remaining populations. Future land clearing will further reduce the species' area of occupancy and increase fragmentation of remaining populations.

The reliance of most GSM populations on the main host plant *Lomandra maritima*, means that much of the potential and occupied habitat includes areas zoned for future urban and other development. This is particularly the case in the coastal and sub-coastal parts of the greater Perth region, especially in the north-west corridor. This creates an urgent need to better clarify the habitat and distribution of the species to ensure that conflict between the conservation of this species and development is minimised.

This project aims to identify key graceful sun-moth (GSM) habitat for conservation, refine knowledge of the species' distribution, genetic structure, biology and habitat requirements, primarily to resolve potential conflict between GSM conservation and urban development, and ultimately to conserve the species. March 2010 surveys identified new populations of the species and significantly extended the known range of the species. This necessitates further work to be undertaken to clarify the distribution and ecology of the GSM. The project will resolve gaps in knowledge of the biology and habitat requirements of the GSM by determining the full extent of its distribution, the causes of past local extinctions, the long-term viability of extant populations, and the abundance and density of host plants required to sustain populations.

Perth Zoo's horticultural contribution to conservation

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Perth Zoo's Horticulture Team regularly contributes to conservation knowledge. Examples include expertise in areas such as:

- Monitoring of orchids and other plant species at Perth Zoo's property at Baker's Hill.
- Successfully transplanting large numbers of native terrestrial orchids from construction sites to Perth Zoo.
- Creating plant and animal habitats for threatened species in non-endemic locations.
- Large scale production of food plants for native and exotic threatened fauna.
- Working with and encouraging local landholders in high biodiversity hotspots.

Perth Zoo also has a range of opportunities for threatened species research and collaboration:

- Two properties containing virgin bush, at Baker's Hill and Byford.
- Expertise in working at the nexus of flora and fauna needs.
- An unusually diverse range of fungi located in the Zoo grounds.

Fungi nourish Gilbert's potoroo from the brink of extinction

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Gilbert's potoroo was presumed to be extinct until being rediscovered in 1994 at Two Peoples Bay Nature Reserve - the animal's only known natural refuge. Fungi largely determine the survival and breeding of Gilbert's potoroos because truffles are their major food. Therefore we needed to determine if potoroos translocated into new areas could find enough fungi to survive and breed. We also needed to determine what types of areas and vegetation may be suitable for translocations. The diet of potoroos translocated to Bald Island was assessed by examining their scats within days after their release, and again 1 and 2 years later. Four potoroos released into the shrubby vegetation of Bald Island only 4 to 8 days previously were found to have consumed 23 species of fungi. No plant material, insects or other animal material was present in the scats. Consumption of fungi was sustained over time. Three potoroos released onto Bald Island 1-2 years previously and one island-born individual were found to have consumed 27 species of fungi during a two day sampling period. This included successfully reproducing individuals. Potoroos translocated into other areas with different types of vegetation were also able to rapidly find diverse truffles, e.g. two potoroos in a mainland site dominated by eucalypt woodland consumed 14 species of truffles within 3 months. This study confirmed that sustained survival and breeding of translocated potoroos at sites with at least two different vegetation types parallels sustained production and consumption of a wide diversity of fungi. To help determine the suitability of other target areas for future translocations the abundance and diversity of fungi at the sites should be pre-assessed.

Plant communities and threatened flora of seasonal clay-based wetlands of south-west Australia; weeds, fire and restoration possibilities.

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The plant communities of seasonal clay-based wetlands of south-west Australia are amongst the most threatened in Western Australia. Over 90% have been cleared for agriculture and urban development with weed invasion a major threat to those that remain. The South African geophyte, *Watsonia meriana* var. *bulbillifera*, is particularly invasive within these communities forming dense monocultures displacing the herbaceous understorey. Significantly over 50% of the flora of clay-based wetlands are annual and perennial

herbs and include a number of threatened taxa including *Centrolepis caespitosa, Schoenus natans, Craspedia argillicola* and *Aponogeton hexatepalus*.
Meelon Nature Reserve, a remnant clay-based wetland on the Pinjarra Plain 200 km south of Perth, has been the focus of a five year study investigating the effectiveness of the herbicide 2-2DPA (Dalapon®, Propon®) in controlling populations of *W. meriana* var. *bulbillifera*. The impacts of the herbicide on native flora, the response of the native plant community to *W. meriana* var. *bulbillifera* removal, and the compounding impacts of fire have also examined.
In the first year of the control program, a 97% reduction in the cover of *W. meriana* var. *bulbillifera* was recorded. Importantly this was associated with no significant decrease in the diversity or abundance of native flora. Eighteen months after the initial herbicide treatment an unplanned wild fire burnt through the reserve, facilitating a significant increase in cover and diversity of native species in the treatment areas. Indications are that plant communities of the seasonal clay based wetlands of south-west Australia have the capacity to recover following major weed invasion and that fire can play a role in the restoration process. Implications for the management of the rare flora of clay-based wetlands across south-west Australia will be discussed.

Biotechnology for *ex situ* conservation and *in situ* recovery of rare and threatened West Australian flora.

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The South West Australian Floristic region (SWAFR) is an internationally recognised biodiversity hotspot characterised by highly infertile soils within a very old and weathered geographically isolated landscape. Partly as a result of these factors the SWAFR carries a predominantly endemic flora with over 7,000 species indigenous to this region. However, threatening processes such as clearing, salinity and weed invasion combined with climate change pose significant challenges for conservation and restoration efforts which are likely to be exacerbated in future.
Approximately 2,600 plant species in WA are currently listed as priority flora within which 391 plant species are declared rare (DRF). As nearly three quarters of WA's DRF reside outside conservation reserves, often in isolated and fragmented populations, *in situ* conservation is often difficult and problematic; hence the only recourse in many cases is the establishment of *ex situ* collections as an interim measure to prevent likely extinction. However, the use of seeds for the establishment of such collections in some cases is not a viable option due to low seed set and poor seed quality or intractable deep seed dormancy. Additionally, for critically rare species where only a handful of individuals remain the retention of every remaining parental genotype is of paramount importance to negate the deleterious effects of continuing genetic erosion. Under such circumstances, the development of specific tissue culture or other biotechnology approaches may be the only viable but nonetheless challenging option for the establishment of *ex situ* collections or for the production of plants for re-introduction. For plant tissue culture to be successful under such circumstances it is necessary to initiate culture lines from limited often poor quality vegetative material which can require considerable development of nutrient media, plant growth regulator regimes and incubation conditions to optimise shoot regeneration and multiplication especially with woody species of the SWAFR. Once established in a tissue culture system further work is required to then stimulate root induction and proceed with acclimatization and eventually deflasking to produce healthy viable plants that are adapted to nursery or field conditions. While many challenges still remain with utilising TC as a conservation tool there have nevertheless been many notable success stories over the last 15 years including the Meelup and Eneabba Mallees (*Eucalyptus phylacis* and *E. impensa*), Bailey's Symonanthus (*Symonanthus bancroftii*), Sticky Eremophila (*Eremophila resinosa*), *Synaphea stenoloba* and *S. quarzitic, Grevillea scapigera, G. althoferorum* and the Red Snakebush (*Hemiandra rutilans*). More recently, several new projects have commenced on two critically endangered species of *Commersonia* (*C. adenothalia* and *C.* sp. Mt Groper) and the priority species *Leucopogon* sp. *ciliate*, as part of on-going research programs to conserve and restore additional WA species as they are faced with uncertain futures in these rapidly changing times.

Cost effective approaches to threatened species management: the south coast integrated fauna recovery program

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It is widely acknowledged that conservation of threatened species one by one is expensive, and may be ineffective if threatening processes are not managed in a holistic fashion. On WA's south coast, the Western Ground Parrot has suffered precipitous decline and is heading to imminent extinction, despite considerable efforts to manage the population. This has stimulated concern that a number of other threatened animal species in this area may suffer a similar fate.
Our approach has been to identify the major likely threatening processes, in particular wildfire and predation. In the past ten years wildfire suppression and proactive fire management has mitigated the threat of fire, but population decline has continued. During the past 18 months we have commenced implementation of an integrated introduced predator control program in an adaptive management framework. The purpose of this collaborative approach has been to implement management action immediately, but in a way that will allow us to determine the actual impact of predation by foxes and cats, so that we can evaluate the efficiency of the action and its impact on an array of threatened species including the Dibbler and Chuditch. Trials already carried out indicated that the proposed management actions would not impact negatively on non-target species. Because of the dire position of the Western Ground Parrot, we are putting in place an 'insurance policy' for this species through captive management for future reintroduction. The success of the program is dependent on significant volunteer input.
Outcomes of this project will provide important lessons that could be applied across the state and elsewhere. But despite the long-term conservation benefits that could flow from such an approach in terms of value for money, current funding and resource allocation arrangements have proved to be a major challenge to implementation.

Conservation genetics of threatened species in the diverse flora of Western Australia

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The Western Australian flora has many species, including a high proportion that are rare and threatened, with geographically restricted distributions and distinct evolutionary lineages that may be relictual or recently evolved. The genetic complexity of the flora is reflected in disjunct distributions and fragmentation within the landscape despite a relatively stable evolutionary history. Assessment of the level and structure of genetic diversity within and among populations of threatened species enables identification of management units and prioritisation of populations and species for conservation management. Clonality within species makes assessment of census size of populations difficult and genetic analysis can assist in identifying the size and spatial pattern of clonal patches. The conservation status of rare species suspected to be of hybrid origin requires further evaluation according to additional criteria and confirmation of recent hybrid origin of these species facilitates effective identification of their conservation status. Populations of threatened species are often small and isolated and may be subject to increased inbreeding and genetic drift. Knowledge of mating system variation, inbreeding, gene flow among populations and levels of genetic diversity is important in designing conservation strategies that maintain effective breeding systems to support population persistence. To date 48 threatened taxa have been investigated using a range of genetic approaches. Examples will be presented of how evaluation of genetic factors in threatened species have provided a context for understanding rarity in the diverse Western Australian flora, and facilitated development of management strategies for conservation of rare and threatened species.

Threatened flora research in the Department of Environment and Conservation: preventing extinction and enhancing recovery.

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Threatened flora research activities in the Department of Environment and Conservation are focussed on developing an improved understanding of factors and processes that are critical for the conservation of the State's threatened plants. Major objectives include: improving our understanding of genetic and ecological factors that are vital for the long term viability of threatened plant species, ameliorating key threats such as dieback and weeds, developing threatened species reintroduction methodologies and success criteria and improving our taxonomy and identification techniques. The delivery of good science based knowledge for decision making and on-ground management of threatened flora has been broadly based on team projects developed as part of the following key research themes:

- Ecology and population biology of threatened flora
- Seed biology, *ex situ* seed conservation and the Threatened Flora Seed Centre
- Management of threats and threatening processes particularly *Phytophthora* dieback, habitat fragmentation, weeds and inappropriate fire regimes.
- Conservation genetics of threatened flora.
- Experimental translocation and recovery of threatened flora.
- Taxonomy, survey and the listing of threatened flora and Priority Flora (rare and poorly known taxa)

In addition a wide range of adaptive management projects have been set up and implemented by the Department's Regional Services Division and Nature Conservation Division staff. These include assessing various recruitment methodologies including fire to recover declining populations and developing appropriate weed control, *Phytophthora* dieback and canker management strategies to prevent the loss of populations. A major challenge is the large number of threatened plant species that are Critically Endangered (139) that will require the close integration of research and immediate management actions if extinction is to be prevented in the next five to ten years.

Integrating seed science into seed banking provides critical support for threatened flora conservation.

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The Threatened Flora Seed Centre in the Department of Environment and Conservation was established 17 years ago to address the need for immediate *ex situ* conservation through seed banking given the imminent extinction of many populations of threatened flora due to Phytophthora dieback and other major threats such as habitat fragmentation. It has successfully delivered long lasting and practical benefits to threatened flora conservation through the successful banking of seeds, including over 300 of the State's threatened flora, resulting in the provision of genetic material for more than 50 threatened plant translocations.

Research has focussed on the development of reliable techniques for seed germination both as a means for assessing seed viability in storage and importantly for the use of seed in translocations. To date more than 1850 threatened flora seed germinations have been carried out to improve our understanding of dormancy-breaking requirements. The Centre's research into the suitability of international seed storage standards for the Western Australian flora has resulted in the use of standards that will ensure long term seed viability in storage for the majority of threatened taxa. Using a rapid ageing protocol to identify seed longevity, research on cone age and relative longevity of *Banksia* seed has informed collection strategies for threatened serotinous species. Recent studies have involved developing a seed-based approach to predicting species' response to environmental warming, with early indications of a strong negative relationship between percent germination and increasing temperature above a relatively low optimum constant temperature for some restricted Stirling Range flora, in particular the threatened *Sphenotoma drummondii*. Field-based seed research has contributed to an understanding of reproductive biology and regeneration characteristics in threatened taxa such as *Acacia insolita* subsp. *recurva*, *Cyphanthera odgersii* subsp. *occidentalis* and *Grevillea maxwellii* while studies on seed set and viability in *Eremophila* and *Verticordia* species have contributed to a better understanding of seed dynamics in threatened species in these genera. The integration of this seed biology research with seed banking has facilitated the efficient use of scarce seed resources from threatened species and ensured their effective use in threatened species translocations.

Conservation of threatened and relictual invertebrates on the south coast of Western Australia

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On the South Coast of Western Australia a significant number of short-range endemic and relictual invertebrates are known from isolated pockets of relictual Gondwanan habitats that characteristically remain damp and humid throughout the year. Many of these areas support threatened invertebrates, including the Endangered Stirling Range Trapdoor Spider and Critically Endangered Stirling Range Rhytidid Snail and are also refugia for other relictual Gondwanan taxa including declining groups such as Onychophora (velvet worms), Mygalamorphae (including *Neohomogona* spp, and *Austrarchaea robinsi*) and a number of Diplopoda (millipedes) from the genus *Atelomastix*. Modelling of relictual habitats was completed and followed by ground truthing of areas predicted to provide relictual type habitats. Dedicated surveys conducted by WAM and supported by DECs South Coast and Warren regions and South Coast NRM Inc. increased collections of SREs from across the region, significantly increased our knowledge of the distribution and status of threatened invertebrate taxa, and identified a number of taxa that potentially? meet the criteria for threatened.

Due to their restricted distribution and specialised requirements, short-range endemic and relictual invertebrates are at significant risk of extinction from anthropogenic and natural disturbance. The most significant threat to these species is inappropriate fire regimes, and it is anticipated that in conjunction with climate change and other threats this will have a negative effect on the relictual nature of their habitat. Areas of high importance for the conservation of relictual and threatened invertebrates on the south coast include coastal features of the Albany Fraser Oregon, remnant karri and tingle forests, and the quartzite ranges including the Stirling Range National Park. A recovery plan for the currently listed threatened taxa from the latter has recently been completed. The recovery actions include ecological research into the effects of disturbances on habitat and taxonomic research that are required to clarify the conservation and taxonomic status of these taxa. Implementation of these recovery actions is guided by the South Coast Threatened Invertebrate Team and will assist in informing management of the reserves and improve conservation outcomes for threatened and relictual invertebrates.

Noisy Scrub-bird Research and Recovery Program 1964-2010

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Recovery of the Noisy Scrub-bird *Atrichornis clamosus* commenced in the 1960s when the species was rediscovered at Two Peoples Bay, near Albany Western Australia. Since that time monitoring of the population trends has been conducted annually through census of territorial males across the species restricted range between Two Peoples Bay Nature Reserve and Cheynes Beach. Standardised monitoring has recorded a population index increase from around 45 territorial males to over 700 in 2001.

Translocations proved to be the most effective way of establishing new populations, and in 1997 the success of the program resulted in the scrub-bird being downlisted from Endangered to Vulnerable. Following the impact of several large wildfires, including one on Mt Manypeaks in 2004 that resulted in the loss of over 55% of remaining habitat suitable for scrub-birds in the Albany district, the status of the scrub-bird was reassessed as meeting IUCN criteria for Endangered, as the risk of fire impacting on the remaining population had significantly increased.

Research into habitat preferences, both vegetation type and structure and leaf litter food resources, has helped inform the selection of translocation sites and improve understanding of optimal habitat. In addition this work is being used to investigate post-fire seral stage preferences following the Manypeaks wildfire. Research on the social organisation of the species found that males most probably operate in song groups that represent a dispersed lek with a 'hotshot' male determining the repertoire of song groups consisting of up to 8 males. More recently the impact of genetic bottlenecks on population viability and the implications for the translocation program are being investigated.

Improving our understanding of habitat preferences, genetics and the social system of the scrub-bird will inform the long term management and recovery of this species. Long term, ongoing monitoring is essential to put this knowledge in context and to evaluate the effectiveness of management actions.

Comparison of the impacts of plant canker disease and climate on Proteaceae and evaluation of selected fungicides as a management tool for canker control in the threatened flora *Banksia verticillata* and *Lambertia orbifolia*.

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The contribution of canker causing fungi to stem and branch death in South Western Australia is not well documented or understood. Two declared rare flora *Banksia verticillata and Lambertia orbifolia* are currently being severely impacted by canker disease. To quantify and monitor canker severity and impact, permanent transects have been established in *Banksia baxteri*, *B. coccinea, B. verticillata* and *Lambertia orbifolia* with 1620 individuals assessed across 32 sites. Individual cankers have been cultured and preliminary analysis indicates the most frequently isolated pathogenic fungi are those in the *Botryosphaeria* complex, a putative *Microthia*, *Cryptodiaporthe* and *Cytospora* spp. respectively. All except *Cytospora* spp. have been isolated at a low level from healthy asymptomatic tissue suggesting that they have some degree of benign endophytic role and that the environment may moderate the host-pathogen relationship. Co-occurrence of several of the pathogens in single canker lesions also demonstrates a synergism in canker disease expression. Data loggers recording temperature and humidity have been installed at 20 of these sites covering the northern and southern rainfall extremities. Interpolated rainfall, temperature and humidity data for each site are being collected for comparison against canker impact scores in an attempt to develop predictive ability in climate change scenarios. The systemic fungicides fenarimol, prochloraz and tebuconazole are being investigated as control options in *B. verticillata* and *L. orbifolia* – initially *in vitro,* then *in vivo,* for the four main canker causing pathogens.

Measurement of off-target damage to threatened *Tetraria australiensis* from the management of **Watsonia borbonica.* using 2,2, DPA herbicide

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A research trial was established to determine whether the semi-selective herbicide, 2, 2 DPA, would effectively control *Watsonia borbonica* without off-target damage to the declared rare sedge, *Tetraria australiensis*.

Tetraria australiensis was presumed extinct until the population at Watkins Road Nature Reserve in Mundijong was recorded flowering after a wildfire in 1993. The Watkins Road Nature Reserve population is the largest of the 11 known populations and is currently under threat from invasion by W.borbonica, an invasive geophyte that is established in very dense stands across the site. The majority of extant *T. australiensis* populations are located on the heavier soils of the eastern side of the Swan Coastal Plain in plant communities that are currently or potentially threatened by invasion from *Watsonia spp*.

A total of 12 permanent quadrats were set up in recently burnt and long unburnt bushland areas stratified for the presence of *W. borbonica* and *T. australiensis* at Watkins Road Nature Reserve. Controls were established and 2, 2 DPA was spot sprayed on *W. borbonica* at different rates in the burnt and unburnt areas in October 2009. Interim results (Jan 2010) detected no mortality or health effects to *T. australiensis*. There was no significant difference between treatment and control plots for *T, australiensis* cover, frequency, health rating or flowering. Results for *W. borbonica* have been delayed until plants begin actively growing in winter 2010 following the annual period of summer dormancy.

Final results in winter 2010 will demonstrate either an effective management technique for *W. borbonica* control amongst *T. australiensis* populations or a requirement for further trials of other herbicides. This research will fulfil requirements of DEC Conservation Advice for the Recovery of *T. australiensis*; that plans are developed and implemented at the regional and local scale for weeds that threaten *T. australiensis* and that any techniques used for weed management do not have an adverse impact. Final results of this research will be communicated to all land managers of *T. australiensis* populations.

The western ringtail possum, *Pseudocheirus occidentalis*, (Thomas, 1888)

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Listed as a threatened species in Western Australia, nationally and internationally, the western ringtail possum (*Pseudocheirus occidentalis*) is restricted to the south-west corner of Western Australia. Despite this, the current known geographic range of *P. occidentalis* is considerably different from, and more expansive than, published accounts from the 1990s. This most likely represents an increase in knowledge of the species' distribution. Recognised threats to the species persistence include habitat loss, predation, inappropriate fire regimes and effects from climate change. The most immediate threat to persistence of *P. occidentalis* is habitat loss associated with rapid urban expansion in the greater Bunbury, Busselton and Albany areas and introduced predators more broadly. Attempts to mitigate the effects from habitat loss have historically focused on translocation which has met with some success. Low density populations have established at translocation release sites within Yalgorup National Park and dispersal of recruits has been confirmed from genetic analyses. Genetic studies have also revealed no evidence of historic or contemporary mixing of *in situ* (naturally occurring) populations separated by as little as 30 km and with no physical barriers to dispersal or movement. This raises immediate concerns for, and conservation interest in, several recently confirmed populations, including those at Dawesville and Binningup, where development and habitat clearing is proposed. The conservation significance of these populations, in terms of genetics and demographics, is not known.

A high level of *P. occidentalis* predation by feral cats (*Felis catus*) and the south-west carpet python (*Morelia spilota imbricata*) was detected in 2002 - 2004 at Leschenault Peninsula Conservation Park, the primary translocation release site. Recent PhD programs have quantified this high level of predation. Survivorship modelling identified some intrinsic and extrinsic proximate factors affecting the short and long-term susceptibility of translocated individuals to predation. Although no causal link has been confirmed, *P. occidentalis* survivorship was negatively associated with high numbers of the sympatric common brushtail possum (*Trichosurus vulpecula hypoleucus*) and negatively associated with high pre-translocation lymphocyte counts. Reference values and baseline information on the haematological and biochemical profiles have now been established for coastal populations.

Clearing of *P. occidentalis* habitat has continued and pre clearing surveys of population size continues to be based on *ad hoc* consultant derived estimates, despite availability of universally accepted quantitative techniques. Displaced animals are released in unsanctioned translocations at sites determined by wildlife carers. Commonwealth and State assessment processes are inconsistent, as are approval conditions. Untested mitigated measures have been adopted at some sites with minimal or no requirement to monitor the effectiveness of these measures.

Contrasting with this, collaboration between Main Roads WA, Satterley Property Group, Western Power, the Shire of Busselton, the Shire of Capel, UWA and DEC is experimentally trialling use of rope bridges as a measure of mitigating *P. occidentalis* mortality associated with roading and development. The research is incorporating assessment of the value of rope bridges in establishing and maintaining gene flow.

The largest remaining inland population of *P. occidentalis* is located in jarrah forest of the Upper Warren region east of Manjimup. Abundance in the region was negatively related to logging, fire intensity, time since last burn, and the extent of fragmentation by agriculture. Clearing for agriculture has also been selectively biased toward the higher quality *P. occidentalis* habitat, thereby compounding the impact on the population. *P. occidentalis* was also positively related to fox control. Studies on the real-time impact of timber harvesting have demonstrated a significant reduction in survivorship, due principally increased vulnerability to predation, especially by cats, and a sustained population collapse to undetectable levels at a landscape scale in both logged and unlogged jarrah forest in the Greater Kingston area. Key diurnal shelter and habitat elements and their characteristics have also been identified.

The quokka, *Setonix brachyurus*, (Quoy and Gaimard, 1830)

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The quokka (*Setonix brachyurus*) the iconic marsupial, synonymous with Rottnest Island, is listed in Western Australia as "*fauna that is likely to become extinct or is rare*", is listed nationally as "*Threatened Fauna*", in accordance with the EPBC Act and is listed internationally as a "*Threatened*" species in the sub-category of "*Vulnerable*" in accordance with IUCN Red List Criteria.

Rottnest Island is the only place where quokkas occur at high density, however, the Rottnest Island population is anomalous. Rottnest supports a population which has temporarily high numbers but seasonally falls to a much lower, unquantified population size. The quokka also occurs on Bald Island, near Albany and widely in south-west WA. Despite this, population size on the mainland has been quantified for populations from the northern jarrah forest only. The research concluded the northern jarrah forest populations were the terminal remnants of a collapsing metapopulation and recent genetic work has supported this assertion.
Populations from the southern forest and south coast are less well known. However, interim results from a current PhD program have questioned the anecdotally held belief that quokkas are abundant in these areas. Predation by the introduced fox (*Vulpes vulpes*) and feral cat (*Felis catus*) have been implicated as contributing to the quokka's decline in the geographic range since European settlement of WA.
The Rottnest Island population is known to have less genetic variability than mainland populations and recent genetic analyses also identified unique differences in the northern and southern jarrah forest populations. The southern jarrah forest population(s) have a much higher level of diversity, and are significantly differentiated from their northern counterparts.
Climate modelling has identified a real and present threat to long-term persistence of the quokka with populations predicted to contract to the higher rainfall areas of south-west WA. Modelling predicted the extent of range contraction would increase with the severity of the climate-change scenario. The species was predicted to lose all range by the year 2070 under the most extreme climate-change scenario.

Predation by foxes and cats, the ubiquitous threat to biodiversity conservation in Australia. Is it made worse or ameliorated by mesopredator release?

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Predation of native fauna by feral cats (*Felis catus*) and foxes (*Vulpes vulpes*) is listed by the Commonwealth of Australia's *Environment Protection and Biodiversity Conservation Act, 1999* as a key threatening process. In recognition of this, The Western Australian (WA) Department of Environment and Conservation (DEC) and its predecessor, the Department of Conservation and Land Management, implemented broad-scale aerial and ground based baiting for fox control. The operation was based on research which clearly demonstrated a suite of native species would increase in abundance in response to fox control. DEC's 'Western Shield Introduced Predator Control and Fauna Recovery Program' is the umbrella program for fox control in WA.
The initial benefits from fox control were dramatic and culminated in the delisting of three threatened mammal species, the woylie or brush-tailed bettong (*Bettongia penicillata*), tammar wallaby (*Macropus eugenii*) and quenda, or southern brown bandicoot (*Isoodon obesulus*). Translocation of a suite of threatened mammal species also indicated initial success.
Despite ongoing baiting of large tracts of conservation estate, many of the initial fauna recoveries and translocation successes were not sustained. In 2009 the iconic woylie was again listed as a threatened species. Various hypotheses were proposed to explain these declines but none is universally accepted and a combination of causal factors is likely. However, there was strong evidence that predation by cats increased when fox density was reduced. This phenomenon is well documented in ecological theory and is known as mesopredator release. The reduction in density of the dominant predator (the fox in south-west WA) releases one or more subordinate predators (mesopredators) from competition. The results of this 'release' can include increased abundance and/or changes in the behaviour of the subordinate predator(s). In south-west WA, species potentially released from competition with foxes include the feral cat and native predators such as goannas (*Varanus rosenbergi* and *V. gouldii),* chuditch (*Dasyurus geoffroii*) and the south-west carpet python (*Morelia spilota imbricata*).
To confirm if mesopredator release of cats was occurring as a result of fox density reduction and if this was contributing to fauna declines, a collaboration was established between the Invasive Animals Cooperative Research Centre (IA CRC), DEC and the Australian Wildlife Conservancy (AWC). The project is comprised of four study sites – the rangelands (Mt Gibson and the former pastoral leases of Lochada and Karara), the northern jarrah forest, Dryandra Woodland and Lake Magenta Nature Reserve. Achieving the objectives required modification of existing techniques and development of a range of new ones, including methodologies to estimate population densities of foxes, cats and goannas, and broad-scale use of hair collecting devices to identify individual foxes and cats from DNA extracted from the collected hair.
The collaboration has enabled the project to meet its major objectives. A refined sandplotting techniques now allow us to estimate fox and cat density instead of relying on simplistic unquantified "indices of activity". Hair collection devices have been developed and enable collection of fox and cat hair from a single device. Genotyping of the DNA recovered from hair and scat samples has shown fox populations are being "turned over" (i.e. individual foxes are successfully removed by baiting, but are replaced by immigration). Genotyping from hairs has confirmed the feral cat bait ERADICAT® is effective in controlling both introduced predators in

the rangelands. Mesopredator release of cats in the presence of fox control has been confirmed at the northern jarrah forest site and at Lake Magenta. Genotyping to identify the predator species and the individual predator has confirmed cat predation, predominantly by male cats, is responsible for the majority (67%) of woylie predation deaths at Dryandra.
Not surprisingly, the research has revealed the complicated nature of predator interactions. At George Forest Block, on the eastern margin of the northern jarrah forest, we have found cats are not the only species to show a mesopredator release response. The fox population is clearly at a lower density than at unbaited sites, yet it appears to provide sufficient competition with cats to prevent the cat population from increasing. We have hypothesised this level of fox density reduction has enabled the observed high density of chuditch and goannas; both appear to have shown a mesopredator release response. Ecological theory predicts as native predator diversity increases, food web stability is enhanced and intra-guild predator interactions increase. This in turn can reduce negative flow-on effects. In keeping with this, we have observed low fox density, low cat density and relatively high native predator (chuditch and goanna) density coincides with a higher diversity of native prey species. The woylie population at George Forest Block is of particular interest. It is possibly the only woylie population to have shown an increase over the past decade.

Bringing it all together – using science as the main tool for improving translocation of rare plant species back into the wild.

Bob Dixon

Manager Biodiversity and Extensions, Kings Park & Botanic Garden

The Botanic Garden and Parks Authority works hand in hand with other government agencies and has a particularly close working relationship with DEC in translocating rare species back into the wild. Many of these long term projects, *Grevillea scapigera* about 20 years, are working well and indications are several should become self sustaining in the long term. Why are they so successful? We have been doing this for a long time and continue to improve our scientific and cultural techniques. The main reason for success is BGPA takes a holistic approach, we have the scientific expertise eg research the biology of the species, genetic provenance, pre-treatments for stimulating seed germination or other methods of propagation such as tissue culture and somatic embryogenesis and can store rare plant material for long periods of time in a specialised seed store or under cryostorage. Our expertise also includes site restoration including weed control (working closely with weed scientists from the Dept of Agriculture), planting and managing the rare species as well as increasing biodiversity which assists in sustaining pollinating agents. Critically endangered as well as priority listed species are translocated and funded by the Commonwealth Government, State Government agencies as well as industry, particularly mining. A range of translocation projects will be illustrated outlining salient points.

The Development of a Conservation Medicine Programme at Perth Zoo

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Conservation medicine, as a distinct discipline investigating health and disease in relation to ecosystems, has grown in recent years. Veterinary teams are developing a growing understanding of the key aspects of conservation medicine, including the potential impact of wildlife disease on biodiversity and the importance of wildlife health within the continuum of human and ecosystem health. Perth Zoo veterinary staff have made a steadily increasing contribution to conservation medicine in recent times. The veterinary and nursing staff provide expert assistance to a variety of external projects with wildlife health outcomes, and are committed to identifying and responding to areas of need in conservation medicine, both within Western Australia and further afield.
This presentation examines the development of conservation medicine at Perth Zoo and describes current and future projects in this area.

Supporting the recovery of the world's rarest marsupial, Gilbert's potoroo, with science: past and current research and future directions

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After the rediscovery in 1994 of Gilbert's potoroo, existing in a single population of less than 40 animals, a program of research to support recovery commenced, with studies conducted in parallel with recovery actions. Intensive studies of home range, spatial organisation, habitat usage, population dynamics and reproduction in the wild provided a strong knowledge base to assist surveys for other populations and to inform future translocation projects.

Initially, the best hope of recovery was thought to be through orthodox captive husbandry. Collaborative research with universities investigated the use of both remote video monitoring and faecal hormone analysis to monitor oestrus and mating in captive potoroos, to allow better breeding management. However the species did not breed well in captivity. Research programs were then implemented: 1) to develop improved captive husbandry methods, with a diet based on nutritional analysis of hypogeal fungi, 2) to develop artificial insemination methods (with Perth Zoo) and 3) to evaluate cross-fostering techniques to increase production and survival of Gilbert's potoroo young (with Zoos South Australia).

At the same time, a trial translocation of wild potoroos to Bald Island was carried out, structured as a research project to maximise the acquisition from the trial of critical information on movements, home range, habitat usage and diet. A full translocation was carried out following the positive results of the trial, with a self-sustaining population as the outcome.

Current research uses the release of Bald Island potoroos into a 380 ha enclosure on the mainland with several different vegetation associations as a means of assessing the breadth of habitat utilisation of which this species is capable. A parallel honours project is assessing the value of fungal diet studies of co-habiting species (bush rats, quendas and quokkas) in predicting food resource availability for Gilbert's potoroos. This technique may assist the selection of suitable habitat for Gilbert's potoroos in higher rainfall zones to allow planning for future artificial migration episodes in a scenario of climate change

The role of research in numbat recovery: no time to rest on laurels

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In 1960, wildlife scientist John Calaby wrote that the numbat was one of the more abundant of the small mammals of south-western Australia. By the early 1980s only two populations and about 300 individuals remained. Little was known about numbat biology at that stage, mainly due to two factors: their lack of response to standard trapping methods and the difficulty of keeping them in captivity. In regard to the high risk of extinction of the species, there was no clear course of action: hypotheses as to the causes of decline ranged from inappropriate fire regimes in forest habitats and the effect of recent drought to increased predation by foxes. Research was carried out into the status of numbats including detailed studies of individuals and investigations of response to fire at Dryandra and Perup, and an experiment comparing changes in numbat numbers in areas baited for foxes versus unbaited areas within Dryandra. The result was a clear indication that numbat abundance was being regulated by fox predation.

Operational fox control was implemented at Dryandra and with the rapid growth of the population, wild-wild translocations were carried out to other areas, also under fox control. New populations flourished and this work became one of the case studies underpinning the Western Shield program, which commenced in 1996. Further numbat translocations were carried out in an adaptive management framework, with monitoring results being used to redesign translocation strategies and influencing choices of new sites.

Since the rapidly growing population at Dryandra crashed in 1994-1995, there has been no recovery but slow decline of that population. A new research program to investigate the causes of mortality in juvenile numbats has raised the strong possibility that predation by cats explains the lack of numbat population recovery. Studies on predation of woylies at Dryandra by Nicky Marlow and her group have gathered strong evidence that cat predation is highly significant there. If cats are now favoured by the intensive fox control at Dryandra, the introduction of an integrated predator control program with parallel studies of impacts on a range of species at risk from predation and/or non-target baiting effects is essential.

How rare and threatened flora management is enhanced by vegetation survey

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Initially the significant interaction between plot based vegetation surveys and rare and threatened flora management is not oblivious but relates to the general poor knowledge of species distributions across this vast State. While major biomes are well delineated detailed distribution information on most of the estimated 12,000 taxa occurring in Western Australia is still lacking. Plot based vegetation surveys have been undertaken at variety of scales across Western Australia for the last 25 years. One of the recurring patterns found from these surveys is the discovery of new populations of rare and threatened flora in addition to the identification of new taxa that are in some cases are subsequently listed as threatened. The recently completed surveys of 24 Banded Iron Formation Ranges established some 1217 plots and recording over 900 taxa. Twenty one taxa were recognized new, and more than 100 new populations of DRF and priority taxa were found. Several of the new taxa were quickly added to the threatened species list as their localised distributions overlapped proposed mining developments. These surveys have also documented ranges extensions of threatened taxa previously thought to have very restricted distributions. The systematic nature of plot based vegetation survey ensures that distributional information of cryptic as well as common taxa is captured in both survey and herbarium databases. The distributional information on rare and threatened taxa captured by plot based vegetation survey has considerably enhanced rare flora management over the last 25 years.

The Western Australian Museum's role in threatened species research: documentation, identity and patterns

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The decline in global biodiversity continues at an unprecedented rate. The identity of the species involved is central to our understanding of threatened species conservation and it is a principal responsibility of the Western Australian Museum to document the identity of the State's fauna. The identity of species in most groups of vertebrate fauna has been well documented and accepted, however, that is not the case for most invertebrate groups. Invertebrates comprise only 37% of the listed threatened fauna species in Western Australia, despite constituting nearly 97% of the fauna. The lack of detailed knowledge of the invertebrates is a serious impediment to their conservation and taxonomic resolution, particularly as the criteria for listing as threatened taxa require assessment of abundance and range reduction. Research at the Museum is focused on resolving faunal systematics in selected groups and, to provide guidance on these issues, detailing their phylogeography, and this necessitates both extending to and receiving from some extra-limital research. The majority of threatened invertebrate species are those where specific taxonomic expertise has resolved issues of identity thereby enabling research on and recognition of their restricted distributions. Despite the central role of invertebrates in ecosystem function and provision of ecological services most invertebrate species are neither described nor their distribution and biology understood. Several examples of invertebrate species identity research and establishment of their unique phylogenetic relationships are evidenced by recent work at the Museum. Two case studies are presented: (i) a systematic study using morphological and molecular methods of the schizomid fauna of the Pilbara, which directly led to the listing of several species by the Minister for the Environment; and (ii) the recognition of large number of suites of species each endemic to a small groundwater region. The Museum also has a research focus on the systematics and phylogeography of vertebrates. The recent resolution of the taxonomy in a widespread scincid lizard taxon documented numerous cryptic species including a short-range endemic species from near Karratha, amidst some major developments. It was only the after the resolution of the taxonomy and delineation of its range that it was identified as a species of concern. DEC is now handling the management plan. Detailed research over the last decade on natural populations of three species of threatened cockatoos and collaborative work with other organizations on their biology, conservation and captive management has provided new and significant information for their conservation and recovery. Recent work on threatened mammals has defined the genetic differentiation occurring within populations of the Northern Quoll in Western Australia and shown these to differ from populations in the Northern Territory.

Western Australia's rich subterranean fauna and its conservation, with focus on the schizomid fauna

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Western Australian subterranean ecosystems have, over the past two decades, become some of the best explored and documented in the world. The presence of numerous endemic clades of troglofauna (air-breathing animals) and stygofauna (aquatic animals) is now documented for many Western Australian regions but the formal description of these taxa is slow. The reasons for this rich diversity lie partly in the longevity of the landscape in which they occur, much of which has been permanently above sea-level and not subjected to perturbations such as glaciations or volcanic flows. Troglobitic fish, eels, arachnids, insects, crustaceans, myriapods, and others, have been found, many of which are short-range endemic taxa. Some have been listed as threatened under the Western Australian Wildlife Protection Act. As an example, recent research into the arachnid order Schizomida has used morphological and molecular data to identify species, postulate their relationships and document their ranges. Pronounced genetic structuring at a fine spatial scale closely corresponded to individual mesa landforms in the Pilbara. The magnitude of this genetic divergence was consistent with each mesa being inhabited by a unique schizomid species. Species status was also confirmed by small, consistent morphological differences. The long separation of individual mesas has isolated individual schizomid populations, ultimately leading to different species. Due to current and impending mining approvals many of these species have been listed as threatened species.

Recovery of the Chuditch *Dasyurus geoffroii.*

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The carnivorous marsupial, the chuditch *Dasyurus geoffroii* formerly occurred in every mainland State and the Northern Territory. By the 1950s this range had contracted to the south-west corner of WA. In 1983, it was listed as fauna that is rare, or is likely to become extinct, under the State's *Wildlife Conservation Act (1950).* In 1992 it was listed as Endangered under the Commonwealth's *Endangered Species Act 1992*. Following a review in 1996 it was listed as Vulnerable under the Commonwealth's *Environment Protection and Biodiversity Conservation Act (1999).* A recovery plan was prepared in 1994, and a recovery team formed to oversee implementation of the plan. Many of the recovery actions were derived from research undertaken into chuditch distribution, biology and ecology in the jarrah forest between 1986-1989 and a wildlife management program published for the chuditch in 1991. This work estimated that only 6000 chuditch persisted in the south west at this time.

The chuditch recovery plan identified six recovery actions:

1. Investigations into the impact of timber harvesting.
2. Investigations into the impact of prescribed burning.
3. Investigations into the impact of foxes and fox control.
4. Undertake captive breeding.
5. Translocate to areas outside current (1992) range.
6. Monitor existing and translocated populations.

Criteria for success:

- > 1 % trap success rates at monitoring sites.
- Establishment and maintenance of at least one semi-arid populations.
- Establishment of at least one self-sustaining population outside the 1992 range.

Research into actions 1 and 2 found no detrimental impact to local chuditch populations from these two management operations. Likewise fox control by means of 1080 poison baiting showed an initial positive correlation to chuditch abundance. Trials with dried meat bait and subsequently with sausage type (Probait) showed that chuditch do find and consume baits but appear unlikely to consume sufficient quantities to be at risk. Captive breeding in collaboration with the Perth Zoo was highly successful with 339 individuals being available for release into 6 sites over 10 years from this source. Four translocations are considered successful with the Lake Magenta and Kalbarri populations meeting the criteria to establish a semi arid population and one outside 1992 range. Long term monitoring sites maintained under Western Shield indicate that the >1% trap success criteria is being maintained but they also fail to show positive trends. A subsequent review of conservation status indicated that it was premature to consider removing chuditch from State and Commonwealth threatened fauna lists.

Cryopreservation of threatened West Australian species

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Cryogenic storage techniques have been developed and adopted for over 100 mainly agricultural plant species worldwide and within Australia at least 30 endangered plants have been stored long-term using cryogenic approaches including Western Australian declared rare flora (DRF) such as *Anigozanthos viridis* ssp. *terraspectans*, *Conostylis dielsii* ssp. *teres, Conostylis wonganensis, Eremophila resinosa*, *Grevillea dryandroides* ssp. *dryandroides*, *Grevillea dryandroides* ssp. *hirsuta*, *Grevillea flexuosa*, *Grevillea maccutcheonii*, *Grevillea scapigera*, *Hakea aculeata*, *Hemiandra gardneri, Lechenaultia laricina*, *Leucopogon obtectus*, *Pityrodia scabra, Philotheca wonganensis, Ptychosema pusillum* and *Rulingia* sp. Trigwell Bridge. Nevertheless, while the benefits of cryogenic storage have been widely acknowledged and indeed the process adopted for readily amenable agricultural/horticultural species such as potato (*Solanum* spp.), pear (*Pyrus* spp.) and banana (*Musa* spp.) there are many species that are currently very difficult to impossible to cryopreserve using current approaches. Therefore, in some respects organizations such as Kings Park and Botanic Garden that utilise cryogenic storage techniques are at a cross road in their endeavours to cheaply and effectively store a wide selection of species and genotypes for conservation purposes.
Indeed, accelerating losses of plant biodiversity worldwide for both native species and agricultural “heirloom” or “heritage” varieties has meant conservation agencies are obliged to pursue more efficient methods of dealing with long-term storage of germplasm of critically endangered flora. Seed storage remains the most common form of germplasm storage for most agencies committed to plant conservation but has limitations in terms of seed quality and seed availability issues, seed dormancy and maintenance of parental genotypes. Tissue culture, while now almost inseparable from most germplasm conservation programs also has limitations in terms of cost of maintenance and somaclonal mutations that commonly occur in long-term cultures. More advanced methods of long-term tissue culture such as arrested or slow growth (through reduced incubation temperatures or incubation on growth retardant media) do not wholly solve the problems of contamination, on-going maintenance, space issues, and loss of genetic fidelity over time. Cryostorage offers a space and cost efficient alternative to conventional tissue culture approaches while virtually eliminating genetic erosion by virtue of the total arrest of biochemical function at the temperatures of liquid nitrogen (–196 °C). Coupled with increasing accuracy and decreasing costs of molecular methods of monitoring genetic fidelity, cryostorage can be used with confidence when the techniques and approaches have been fully developed.
Nevertheless, for taxa that are not amenable to current cryogenic approaches new ways of developing cryogenic storage techniques need to be investigated including research and development into the ways in which cell membranes interact and change when cooled to liquid nitrogen temperatures in the presence of various antifreeze compounds such as glycerol, DMSO and ethylene glycol, an approach that will increasingly involve novel cross-disciplinary collaborations. By focussing on representative species these new approaches aim to integrate laboratory and modelling findings to provide guidelines for the development of new cryopreservation protocols and to assess the robustness of theoretical models in predicting optimum cryogenic conditions.

Weeds and Threatened Flora

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There are 1,233 naturalized vascular plant taxa recorded for Western Australia, composed of 12 Ferns, 15 Gymnosperms, 345 Monocotyledons and 861 Dicotyledons. Of these, 677 taxa (55%) are environmental weeds, recorded from natural bushland areas. Another 94 taxa are listed as semi-naturalised garden escapes. Most are herbaceous annuals or grasses with the largest groups being the Poaceae (196), Asteraceae (115), Papillionaceae (106) and Iridaceae (53). The largest numbers of weeds are recorded from the natural regions encompassing the capital Perth, with 801 and 705 recorded for the Swan Coastal Plain and Jarrah Forest Bioregions respectively.

Recently DEC has completed a State-wide prioritization process on all weeds and their effects on biodiversity values, including threatened flora. There are at least 123 weeds that occur with, directly compete with or detrimentally alter the habitat of threatened flora. Of these 22 (mainly grasses and bulbous species) are serious threats to the persistence of threatened flora and will require asset based plans to lessen their impact.

Practical conservation outcomes from genetic studies on Western Australia's rare flora

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Modern molecular tools and methods of analysis provide new opportunities for the powerful assessment of genetic variation and genetic processes within and among populations. At Kings Park, these tools are being applied for tangibly positive conservation outcomes for rare and threatened flora. Recent outcomes include:

- identification of morphologically cryptic species from DNA sequence variation, in genera such as *Lepidosperma*.
- identification and subsequent reversal of the rapid loss of genetic variation and fidelity in rare species recovery through translocation and *ex situ* conservation, such as DRF *Grevillea scapigera*.
- confirmation of the genetic fidelity of cryopreserved rare-plant material in ex situ collections, such as DRF *Anigozanthos viridis*.
- assessment of clonality within natural populations of rare species, such as *Grevillea pythara*.
- application of DNA barcoding for the rapid taxonomic identification of potentially impacted rare flora from morphologically ambiguous collections, such as DRF *Eucalyptus articulata*.
- assessment and quantification of population genetic variation to be removed by proposed mining activities, such as DRF *Darwinia masonii*.
- characterisation of key population processes such as mating system and pollen dispersal to establish a pre-impact benchmark for the effects of mining activity on these processes, such as in the DRF *Tetratheca paynterae*.
- genetic characterisation of significant conservation units within species, such as the DRF *Caladenia huegelii*.

Perth Zoo husbandry and reproductive research supporting conservation programmes,

J. Lemon, A. Ferguson, H. Robertson

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Perth Zoo staff supports a number of other research projects conducted by both in-house by PZ staff and externally by visiting researchers. Current projects involving Australian species include:

- Short beaked echidna reproduction, growth and development.
- Evaporative water loss and relative economy of marsupials.
- Investigation into the role of nest box temperature as a factor influencing the successful rearing of parent raised Little Blue Penguins at Perth Zoo
- DNA-based faecal analysis to determine diet composition of Little Penguins.
- Beak measurements in juvenile Little Penguins
- Torpor and activity in the dibbler, *Parantechinus apicalis*

Dispersal and survival of threatened Black Cockatoos in South-west WA

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The Department of Environment and Conservation has been actively involved in a program to enhance the capacity of wildlife carers to rehabilitate three species of threatened black cockatoo (Carnaby's, Baudin's and Forest Red-tail) for release back into the wild. DEC staff have now overseen the successful release of more

than 173 (77 banded and 96 unbanded) birds and following the releases in the last three years we are confident that the rehabilitation techniques and release protocols used provide very high survival rates. One of seven Forest-red tailed black cockatoos has been recovered (14km and 2 wks post-release), none of 22 Baudin's black cockatoos and three of 48 Carnaby's cockatoos (up to 10km and 1 mth post-release). A further 189 Carnaby's cockatoo chicks have been banded in the nest, with four of those bands being recovered (up to 103km and 14 months post-banding). One banded bird was recovered at Munglinup during the mass-death event associated with the January 2010 heatwave on the south coast. Carnaby's cockatoo chicks are wild-caught at a range of sites from Coorow in the north, south to Borden and east to Lake King, measured and leg banded to provide data on the survival and dispersal. Breeding has been recorded in two species of rehabilitated cockatoos (Carnaby's and Baudin's) following release in each of two years.

FORESTCHECK – monitoring biodiversity in jarrah (*Eucalyptus marginata*) forest managed for timber harvesting

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Monitoring forms the basis for adaptive management, which is recognized as an appropriate strategy for managing under conditions of uncertainty and change. FORESTCHECK is an integrated monitoring system that has been developed to provide information to forest managers in the southwest of Western Australia about changes and trends in key elements of forest biodiversity associated with management activities. Integrated monitoring is a fundamental component of Ecologically Sustainable Forest Management (ESFM) and is necessary for reporting against the Montreal Process criteria and indicators for ESFM. FORESTCHECK is included as an operational program in the current Forest Management Plan 2004-2013. Monitoring protocols were developed over 2 yrs with input from scientists and managers in the Department of Environment and Conservation (DEC) and a number of external scientific agencies. The Science Division of DEC is responsible for implementation of the project.
The initial focus of FORESTCHECK is on timber harvesting and silvicultural treatment in jarrah (*Eucalyptus marginata*) forest which includes shelterwood cutting, gap creation and post-harvest burning. The sampling design includes external reference sites in old-growth stands, and mature stands that have not been harvested for at least four decades. Between 2002 and 2006 a total of 48 monitoring grids were established at five locations chosen to reflect underlying patterns of moisture availability and fertility across the southwest forest landscape. Each 2 ha monitoring grid is assessed for attributes including forest structure, soil disturbance, litter and woody debris, and elements of biodiversity including vascular flora, vertebrate fauna (birds, mammals and reptiles), cryptogams (lichens, liverworts and moss), macrofungi and invertebrate fauna. Results from the initial five years of monitoring are currently being analysed in preparation for publication.
While not specifically designed as a monitoring program for threatened species, FORESTCHECK provides valuable information about distribution and status of a number of threatened taxa. For example, vertebrate trapping conducted in Donnelly District as part of the monitoring program has contributed to an understanding of the how woylie populations respond to timber harvesting, while trapping in Blackwood District provided information about the dispersal and persistence of translocated woylie populations. Collection and description of large numbers of invertebrates and fungi also adds to the knowledge of these important groups and provides a more robust basis for determining the conservation status of particular taxa, most of which have not been extensively collected.
FORESTCHECK is included in the network of Australian Long Term Ecological Research (LTER) sites. The Concept Plan, Operations Plan and Annual Progress Reports may be viewed on the DEC website at http://www.dec.wa.gov.au/content/category/41/833/1817/.

Microhabitat requirements of the critically endangered orchid, *Drakaea elastica*

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Conservation of complex ecosystems and threatened species requires a detailed understanding of their critical ecological requirements. In order to assist with guiding conservation actions regarding habitat protection, we investigated the multi-scale habitat requirements of *Drakaea elastica*, a nationally threatened,

sexually deceptive orchid endemic to the Swan Coastal Plain, Western Australia. Thirteen populations of *D. elastica* were selected for study, based on information obtained from the Department of Environment and Conservation and confirmed for suitability in the field. Microhabitat requirements of *D. elastica* were determined by comparing structural habitat characteristics at micro-sites where *D. elastica* grew, to random micro-sites within the boundaries of each population. All populations of *D. elastica* occurred in *Kunzea glabrescens*/*Banksia* spp. dominated vegetation. Analysis suggests that micro-sites where *D. elastica* occurs have a relatively higher proportion of bare sand cover and a relatively lower proportion of leaf litter cover compared to random micro-sites. Sites where *D. elastica* occurs also tend to have low cover values of low to medium (0.5-1m) shrubs. These results confirm the previous expert knowledge that *D. elastica* occurs in open sandy patches within relatively open vegetation; however, this is the first study to quantify this relationship. Further research investigating both patch and landscape characteristics affecting the occurrence of *D. elastica* are planned for the future. This research will contribute to the identification of critical habitat for the conservation of *D. elastica*.

Comparative longevity of orchid (Orchidaceae) seeds under experimental and low temperature storage conditions informs conservation seedbanking decisions

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The Orchidaceae is both the largest plant family and one of the most threatened, with more genera containing species that are under threat of extinction than any other family. Terrestrial orchids are often the first plant species lost from disturbed habitats and present considerable conservation challenges as many are intrinsically rare, with rarity often linked to ecological specialisation in terms of mycorrhizal association and/or pollinator. Currently 36 Western Australian orchid species are declared rare flora and a further 49 are priority taxa. *Ex situ* conservation through seed- and germplasm banks provides the 'insurance' for species loss from the wild. Fortunately, the majority of plant species produce seeds amenable to long-term storage. However, there is wide variation in seed longevity and only a very small proportion of orchid species have been studied in relation to seedbanking. Australian orchids have been a particular focus of the seedbanking research programs of Kings Park and Botanic Garden. Research has identified that orchid seeds usually survive the drying process necessary for storage and suggests that most are amenable to seedbanking under international storage standards (ie at -18°C). However, modelling of seed aging of orchid seeds indicates the perilously short-lived nature of orchid seeds under these conventional seed storage conditions, with predicted storage lives of a few decades at most. Compared to seeds of many other terrestrial species with predicted storage lives in the thousands of years, this research re-enforces a need for specialised storage treatment of orchid seeds. Research into alternative methods of storage using ultra-low temperatures of -80°C and -196°C (cryostorage) suggests orchid seeds are usually stable at these temperatures. Cryostorage is a particularly useful strategy for orchid seed storage as the minute size of orchid seeds allows large numbers of seeds and species to be stored in liquid nitrogen dewars. Further development and adaptation of this technology to orchids can ensure the conservation and long-term future of this enigmatic plant family.

Tools for understanding and responding to rarity.

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Results from a three-year, industry-funded study of *Darwinia masonii* (Myrtaceae) and *Lepidosperma gibsonii* (Cyperaceae) are presented. This industry-funded project examines the ecology and conservation and restoration requirements of these species, both of which are declared rare flora species of the Mt Gibson–Extension Hill range in the semi-arid Midwest. The 2007 approval for mining iron-ore at Extension Hill entailed projected loss of 14-15% of the 16,000 known *D. masonii* and 46% of 14,000 then known (now 18% of 45,000) *L. gibsonii* individuals. *D. masonii* occurs on BIF slopes and associated skeletal soils in a 5.6 × 2 km

area (occupying ~ 100ha). *Lepidosperma gibsonii* is known from breakaways, slopes and gullies on BIF, granite and duricrusts over an 8 × 5.5 km area (~40 ha occupied).

Aspects of two of the project's eleven programs are presented: 1) Population dynamics, with data from 30 permanent plots and including rates of emergence of seedlings and survival of adults in response to experimental fire. 2) Species Distribution Modelling using maxent (maximum entropy) modelling, GIS and environmental correlates. Results from these approaches are used to assess critical environmental interactions for each species, and to guide research into requirements for successful post-mining restoration of populations. Other BGPA research on these species – on the seed and seedbank biology, reproductive biology, population genetics, plant physiology and drought adaptations, root systems, restoration requirements and *ex situ* conservation techniques – is not covered.

Perth Zoo Husbandry and Reproductive Research supporting Conservation Programmes - Western Swamp Tortoise

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Perth Zoo is a partner in the ARC funded project *Ecoenergetics of the Western Swamp Tortoise: Modelling the translocation viability of Australia's rarest reptile under present and future climates*. As part of this project PhD Student Sophie Arnall will study the physiology of WST. Other parts of this study include the impact of temperature on growth and development of eggs and hatchling tortoises, including the impact of using a daily fluctuating incubation temperature on the robustness of tortoises hatched using this method.
PhD student, Danielle Gustiniano, is researching the paternity, sperm storage and sperm competition in the Western Swamp Tortoise.
Perth Zoo Veterinarians are also working with Keeping staff and external collaborators, developing an improved captive diet for WST.

Experimental threatened flora translocations and determining criteria to assess translocation success

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The successful recovery of threatened flora, particularly Critically Endangered species, will rely increasingly on translocations and introductions to secure sites where the amelioration of threats has been successful or where current threats are absent. Translocations are both costly and time consuming and in many cases involve relatively small numbers of plants so it is important that effective and efficient methodologies are developed for establishment and success. The goal of translocations is to create viable self-sustaining populations and it is critical that adequate, meaningful and measurable success criteria are developed to accurately assess whether this goal has been achieved. Appropriate success criteria will also enable the assessment of possible changes in a species listing and prioritization of resources. Translocations or preparation for translocations have been identified as a recovery action in most of the 108 approved and 12 draft Interim Recovery Plans for threatened plant species. Translocations have been implemented by The Department of Environment and Conservation for 56 threatened species over the last 17 years. Of these 29 have been experimental translocations with ongoing monitoring accessing a range of establishment, reproductive and recruitment criteria as measures of success. In species such as *Lambertia orbifolia* third generation recruits have now established. Recently more detailed experiments are currently underway to evaluate the effects of nursery pretreatments, time of transplant, microhabitats, and different watering treatments on seedling growth and survival of two Critically Endangered species *Acacia awestonia* and *Banksia ionthocarpa ssp ionthocarpa*. These will involve identifying factors affecting seedling growth and survival by closely monitoring both seedling physiological activity (e.g. chlorophyll fluorescence, leaf temperature as a proxy for seedling transpiration) and changes in local abiotic factors (e.g. soil moisture, temperature, radiation). We are also investigating other options for assessing success such as Population Viability Analysis and estimating mating system parameters and genetic diversity. Although the development of workable success criteria for plant translocations requires further investigation studies to date have been invaluable in improving establishment rates, survival and recruitment in recent translocations.

Fauna reconstruction in the WA rangelands.

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The arid rangeland areas of Australia have suffered a high rate of loss of mammal fauna in the past 200 years. Of the 85 species of terrestrial native mammals known to have once occurred in the arid zone, 11 are now extinct, another six are found only on offshore islands, and 16 are now severely restricted in their range.
A program to reconstruct the native mammal fauna of the rangelands is underway on two former pastoral leases – Lorna Glen and Earaheedy – 1100 km north east of Perth. This is one of the ecologically integrated components of the Rangelands Restoration project, which aims to restore natural ecosystem function and biodiversity at a landscape scale.
Since acquisition of the properties by the WA Government in 2000 there has been control of introduced herbivores (camels and cattle), carnivores (cats and foxes) and implementation of ecologically appropriate fire regimes to maintain a diverse heterogenous landscape. We now aim to reintroduce 11 species of mammals, most of them threatened taxa, that were formerly present in this area, over an 11 year period. In 2007 and 2008 bilbies (*Macrotis lagotis)* and brushtail possums (*Trichosurus vulpecula)* were reintroduced and have successfully established at Lorna Glen. Mala (*Lagorchestes hirsutus*) were released in 2008 but did not establish due to predation by feral cats and native predators. A revised reintroduction strategy was developed and adopted in 2009 with the construction of an 1100 ha acclimatization pen and an expanded feral cat baiting program. In 2010 boodies (*Bettongia lesueur*) and golden bandicoots (*Isoodon auratus*) were translocated from Barrow Island and released into the acclimatization pen. A PhD study is being undertaken on these to determine the role that disease, founder numbers and founder source have on the success of fauna translocations.
These reintroductions will improve the conservation status of arid zone mammals and, in doing so, return many important ecological functions such as soil cultivation through digging and burrowing, nutrient recycling, seed dispersal and grazing and browsing. This is the first time fauna reintroductions have been attempted in the WA rangelands without use of predator-proof fences.

Conservation genetics of narrow range endemic flora on BIF ranges of mid-west Western Australia

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A significant conflict currently exists between the economic objectives of iron-ore mining on the Banded Ironstone Formation (BIF) ranges of the Western Australian mid-west, and the conservation of rare species restricted to these ranges. The management and conservation of these species requires an understanding of the extent of impacts from mining on these populations, and on key population processes such as mating and dispersal that affect long-term viability. For rare species of BIF (*Tetratheca paynterae, Darwinia masonii, Lepidosperma gibsonii, Acacia karina*), we have used molecular tools to characterise the levels, and spatial structuring, of genetic variation within and among populations. Our results enable the quantification of genetic variation to be lost under proposed mining activities, from which decisions can be made and strategies can be employed to minimise this loss. Our results have also highlighted that, despite similarly restricted distributions and population sizes, levels and structuring of genetic variation within these species is not predictable. In addition, we have used these molecular tools to characterise patterns of mating and pollen dispersal, that establish a pre-mining benchmark for the future monitoring of impacts on these key population processes. Molecular phylogenetic studies on these species, and their closest relatives, have revealed the evolutionary relationships of impacted species, informing decisions on the investment of resources for conservation and management. These studies highlight the contribution of conservation genetics to the management of rare species of BIF impacted by mining.

Health Status and disease of a threatened marsupial, the Quokka (*Setonix brachyurus*); implications for conservation.

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This study aims to assess the health status of the Quokka in both mainland and island populations and to determine the impact that disease may have on the conservation status of the species.
Intended outcomes include: Development of a qualitative disease risk assessment for WA macropod species; Prevalence of disease amongst and between populations; Comparison/analysis of disease prevalence with other biological and environmental parameters; Preliminary development of an approach to evaluate the ability of quokkas to cope with disease insults.

Non-marine aquatic invertebrates: Challenges and case studies

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There are thousands of species of aquatic invertebrates in Western Australia in 13 phyla, ranging from single-celled protozoans to marron. They inhabit wetlands as diverse as groundwater aquifers, rain-filled hollows in trees and massive salt lakes. Very few of these are currently listed as threatened species, though more are members of listed threatened ecological communities, especially as components of stygofaunal communities. A large proportion of aquatic invertebrate species have rarely been collected during survey and monitoring projects, but whether these are threatened is difficult to establish for a number of reasons. Particular challenges include difficulty of identification, taxonomic impediments, the small number of wetlands for which we have adequate data, dispersed datasets, the nature of many Western Australian wetlands (e.g. extreme variability in character), lack of basic biological information for most species, aspects of invertebrate ecology such as short life spans and aestivation, and low community awareness or interest. Most of these are also problems for most terrestrial invertebrate groups. *Parartemia* brine shrimp, which have higher diversity and endemism in southern WA then elsewhere, illustrate some of these problems. The extent of their diversity and distribution in WA has only recently been revealed. One species, *Parartemia contracta*, was listed as a priority one fauna species in 1995 on the basis that it was thought to be rare and restricted, although this is now known to be one of the more common and widespread species of the genus. Other more recently discovered species do appear to be rare and in decline but, despite both broadscale (e.g. Wheatbelt biological survey) and targeted *Parartemia* surveys, an insufficient proportion of potential wetland habitats has been surveyed to determine their occurrence and distribution. Furthermore, the reason for apparent loss of some populations is unclear, although aspects of salinisation appear to be involved. They also inhabit wetlands that are dry more often than flooded so surveying for them needs to be opportunistic rather than fixed time projects. These challenges are not insurmountable but illustrate the need for ongoing collaborative research and data sharing amongst researchers.

Conservation Medicine Initiatives at Perth Zoo - Western Swamp Turtle

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The captive breeding and care of the Western Swamp Tortoise (WST) illustrates PZ veterinary efforts in applying conservation medicine to a captive population. Discussions with the WST recovery team led to Zoo veterinary staff increasing their contribution to this conservation program. Perth Zoo veterinary staff reviewed and improved quarantine and biosecurity practices for WST entering and leaving the captive breeding facility from the wild population, implementing more intensive medical examinations and diagnostic sampling for individuals pre- and post-release. These activities resulted in a comprehensive clinical database for healthy captive tortoises. The increased level of intervention and assessment of individuals is recognised as a vital tool for interpreting and responding to health-related problems which might arise in the wild population. Active discussion with the recovery team has opened further opportunities for involvement in related areas of conservation including an assessment of the risks of climate change on this species and its ecosystem.

Conservation Medicine Initiatives at Perth Zoo - Brush-tailed Bettong

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When a sudden rapid decline in Brush-tailed bettong (*Bettongia pencillata*) numbers in south-western Australia was identified, Perth Zoo veterinarians were invited to participate in a transdisciplinary working group to investigate the decline (Wayne, 2008). PZ veterinary staff attended field trapping sessions, performed veterinary examinations and sample collection on free-ranging bettongs, undertook disease risk analysis studies, reviewed archival health records, analysed and interpreted clinical data in the context of the decline and provided advice to the working group on a comprehensive and cohesive approach to disease investigation. Ongoing financial and staffing commitment by Perth Zoo to the Brush-tailed bettong project has allowed Zoo veterinarians to adopt a consistent, responsive and influential role in the working group and enabled the effective alignment of health and disease investigations with broader ecosystem concerns.

Response to sudden declines: Christmas Island lizards

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Perth Zoo collaborated with Parks Australia North in the first attempts to manage captive populations of two critically endangered skink species endemic to Christmas Island (Blue-tailed Skink *Cryptoblepharus egeriae* and Forest Skink *Emoia nativitatis*).
Veterinarians worked with AQIS to facilitate the transfer of biological specimens from Christmas Island, as part of the Federal Government's commitment to investigate the population declines of native lizard species on the island. Veterinarians also developed biosecurity and health screening protocols to manage any reptiles which might be transferred to mainland Australia for captive breeding in the future. Veterinary and keeping staff visited Christmas Island to advise directly on the husbandry, veterinary management and health screening of newly captured skinks.

Perth Zoo Husbandry and Reproductive Research supporting Conservation Programmes - Frogs (*Geocrinia alba*, *G. vitellina* and *Spicospina flammocaerulea*)

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Perth Zoo initially worked with DEC, UWA and WAM, using 4 years of grant funding from OSTI, to research the husbandry and reproduction of WA's threatened frog species. *Geocrinia rosea* (a common analogue of the threatened *Geocrinia* species) was bred in captivity to F3. *Spicospina* was also bred in captivity. Growth and development of all bred frogs was recorded. Last year, with ~12 months of NRM funding, we commenced a rear and breed for release programme for the two threatened *Geocrinia* species. We expect to have over 75 metamorphs and older *G alba* for release in August.
Our new Postdoctoral Researcher, Dr Lindsay Hogan, will attempt to sex the metamorph frogs using Enzyme Immunoassay prior to release to enable us to release frogs in mixed sex groups.
UWA PhD students Aimee Silla and Sharon Perks have both researched reproduction in WA frogs and have added to the body of knowledge required to allow the commencement of assisted reproduction and/or cryopreservation techniques with WA amphibians.

Perth Zoo Husbandry and Reproductive Research supporting Conservation Programmes - Numbats

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A recently completed analysis of the past 16 years of Numbat breeding at Perth Zoo has indicated that the Numbat colony is reproducing at an overall rate of approximately 50%, well below that achieved for most other species in our breeding programmes, even taking into account the sub-optimal age of many breeding animals. Current research is focussed on (i) investigation into the nutrition of the colony and the development of an improved captive diet and (ii) investigating the point at which reproduction is failing. At present we have positive evidence that females are mating (sperm plugs) but when no py are found subsequently, or py born are later lost, the options for the cause of failure include; lack of viable sperm from male, failure to conceive, failure to carry the foetus to birth, failure at birth or failure of lactation. Through enzyme immunoassay of all reproductive hormones and the stress hormone cortisol, extracted from faecal samples collected daily, we plan to track the progress of each animal in the colony over an 18 month period to determine our point/s of failure to enable a targeted approach to addressing the issue. We will also be analysing both reproductive and thermoregulatory behaviour of the Numbats to determine how they cope through the heat of summer and the cold of winter.

Restoration Ecology and Conservation of Rare Banded Ironstone Endemic Plants in an Arid Biodiversity Hotspot

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Banded Ironstone Formation (BIF) ranges in the Mid West of Western Australia are being developed due to the occurrence of iron ore. These ranges have a high rate of associated rare and/or endemic plant species that pose significant economic impediments to the mining industry. This research is aimed to fast-track conservation research that is critical to ensuring attainment of the dual objectives of resource development combined with sustainable conservation of the unique biodiversity of BIF. The project area is based at the Mt. Gibson mining locale, 350 km north east of Perth in Western Australia. The site contains two declared rare flora species, a mountain bell (*Darwinia masonii*) and native sedge (*Lepidosperma gibsonii*) that are nationally threatened species restricted to the 6km range.
The research program is based on understanding the key aspect of plant adaptations to BIF in maintaining the ecophysiological competitiveness compared to common congeners. The research findings from the ecophysiological research program then form the basis of formulating an integrated approach into conservation and restoration of these two threatened species. This includes investigating soil seed banks for propagule material and devising effective protocols for post-mine restoration.

Prioritisation of *Lambertia* taxa for conservation according to the threat posed by *Phytophthora cinnamomi*

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Lambertia are keystone species within the communities in which they occur. Five of the Western Australian *Lambertia* taxa are threatened flora (Declared Rare Flora) and two taxa have a Priority conservation code. Ranking of taxa according to *Phytophthora cinnamomi* susceptibility is fundamental to conservation options within integrated strategies conserving threatened flora of the South-West Botanical Province of Western Australia. Variation in *P. cinnamomi* susceptibility to infection within the genus *Lambertia* was evaluated by soil and stem inoculation. Mortality score following soil inoculation was significantly positively correlated with lesion score determined by stem inoculation. The resulting scores positioned the *Lambertia* taxa in relation to *P.cinnamomi* susceptibility on the resistance-susceptibility continuum and prioritised taxa in relation to the threat posed by the pathogen. The highest mortality and lesion scores for the rare and endangered taxa

L. orbifolia subsp. *orbifolia*, *L.fairallii,* and *L. rariflora* subsp. *lutea* suggest high risk of extinction to *P. cinnamomi* infestation. Furthermore rare and endangered taxa *L.orbifolia* subsp. Scott River Plains, *L.echinata* subsp. *occidentalis* and *L.echinata* subsp. *echinata* with high mortality and moderate lesions scores are also likely at high risk of extinction to *P.cinnamomi* infestation. For common taxa with restricted geographic distribution, the high mortality and lesion scores for *L.ericifolia* suggest high risk of localised extinction in *P.cinnamomi* disease centres. Positioning taxa on the *P.cinnamomi* resistance-susceptibility continuum needs to be incorporated into extinction-risk methodology in order to prioritise flora for conservation actions according to hazard from the pathogen.

The non-marine Molluscs of Western Australia - their diversity and their conservation.

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The current threat to terrestrial and freshwater molluscan species of the world is due to a complexity of factors but particularly habitat change due to human intervention. The role of molluscan species in our non-marine ecosystems as important contributors to the recycling of nutrients is generally-unrecognised and they are important in the diet of both native vertebrate and invertebrate predators. Recent work on the molluscan species' composition, biology, ecology and distribution has been carried out by the WA Museum and biological consultancy staff in remote areas from the Kimberley through to the Great Southern Region as well as in the Goldfields and the Banded Ironstone Belt. Much of this activity is due to the WA Government's requirement for information on the extent of the impact of proposed industrial and other developments to the non-marine molluscan fauna (particularly SRE's), and has produced mixed results. The information gathered has resulted in many "new" species being recognised, but it has also indicated that at least some of the "old" data is now out of date, as the mid-Twentieth Century mineral boom transformed many localities and their habitats. Using "modern" data, the WA Museum has formed productive collaborations with the DEC; University of Western Australia, Museum Victoria and the Australian Museum to investigate and document the non-marine molluscan fauna of the state. A collaborative project between the DEC, WA Museum and the Australian Museum focussing mainly on the Kimberley Islands has resulted in the collection and subsequent description of many new genera and species of the family Camaenidae, with a very large proportion of these new species having been found on only a single island and they would therefore be considered threatened under the criteria of listing.. The distinctiveness of these Kimberley island taxa has been supported by genetic studies. It has now become obvious that some families, such as the Camaenidae and the Bulimulidae, exhibit a high degree of narrow-range endemism, seemingly related to limits in their biological tolerance and their dispersal ability, intensified by the wide separation of suitable habitats. By contrast, species in other families - particularly those characterised by their small to minute size such as the Pupillidae, Subulinidae, Charopidae and Punctidae - are more extensive than previously demonstrated. Future research aims to resolve the taxonomic status (through morphological and molecular data) of the non-marine molluscan fauna, so that we can better judge the vulnerability of many species and upgrade their conservation status.

Conservation action towards the recovery of the rare and endangered *Caladenia huegelii*

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Caladenia huegelii is an endangered spider orchid endemic to the Swan Coastal plain between Perth and Busselton in southwest Australia. This high profile orchid is now confined to less than 20 populations in fragmented populations in remnant Banksia woodland. Urgent conservation action was required to understand why this species is rare and what could be done to restore this species in its natural habitat. Research demonstrated that C.huegelii has an intimate association with a range limited mycorrhizal fungus, required for germination and growth to maturity, which in turn restricts the distribution of the orchid. In addition, using typical pollinator baiting techniques, a scarcity of its highly specific wasp pollinator was responsible for low fruit set in natural populations. Using optomised propagation protocols in the research laboratories at Kings Park, C. huegelii can now be grown from seed to flowering plant using its specific mycorrhizal fungus and to date, translocation of seedlings into field sites have proven to be successful. Research is now focusssing on understanding the ecological requirements of wasp pollinators in order to restore habitat and wasp populations amongst remant C.huegelii populations.

Taxonomy for conservation – the role of taxonomic research in the conservation of rare and threatened flora in Western Australia

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Western Australia has a very large number of known threatened species of plants: 3227 taxa have a conservation rating under the Department of Environment and Conservation's conservation codes, 393 of which are threatened flora (Declared Rare Flora). We also have many known but currently un-named, and many still-undiscovered taxa. On average, between 50 and 100 new taxa are added to the State's flora every year as a result of biological surveys and herbarium studies. Currently 608 known, un-named taxa have a conservation rating, including 18 DRF. Given that most of the more common species have now been described, a very high proportion of newly discovered taxa are restricted in range and are rare and hence potentially threatened. Taxonomy – the science of resolving and naming taxa – is an underpinning science for ecology, genetics and conservation studies. The Western Australian Herbarium has a strong focus on describing and documenting the State's plants, algae, lichens and fungi with a particular focus on conservation taxa, since it is not possible to adequately conserve a taxon until it is adequately described scientifically. Recent examples of this important role include the description of 17 new taxa with restricted distributions centred around Banded Ironstone Formation ranges in the Midwest, many of which are prospective for minerals, the description of new threatened taxa from the Ravensthorpe-Bandalup Hill area and the Goldfields region greenstones belts, and the recent recognition of a number of new and highly restricted taxa on prospective uranium-bearing calcrete deposits. The Department of Environment and Conservation has a clear and key role in recognizing, characterising and describing these species, in ensuring their protection, and in providing tools to allow them to be recognised, surveyed, and their conservation needs assessed. This work helps provide certainty for environment, community government and industry.

Seed ecology of threatened species: Implication for long-term management.

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For the long-term conservation of threatened flora there are many factors that need to be investigated to facilitate the maximum likelihood that a successful outcome will be achieved (i.e. the species continuing into perpetuity with minimal human intervention). A number of these factors are well recognised including assessing the conservation genetics of the target species (to assess the risks of inbreeding depression and the mixing up of phenotypically similar but genotypically distinct sub-species or even species) and assessing factors that are likely to influence whether nursery-grown plants re-adapt, and survive, grow and reproduce when planted into reintroduction sites. The seed ecology of threatened species is one of those often overlooked research areas that may take longer to yield results (potentially many years) but nevertheless is of significant importance as it will allow current and future managers to predict the likely longevity of the soil seed bank (of a given species) once seeds have been dispersed or even provide information as to the likelihood that a species that is locally extinct (and has not been seen for many years) may still persist in the soil seed bank and what factors are likely to stimulate its germination after many years of absence (i.e. fire or some other type of germination cue). Given that there are 391 West Australian plant species declared rare flora (DRF) many of these are likely to be found persisting in the soil seed bank (to a lesser or greater degree) even if they have not been cited in a particular locality for a number of years. Therefore, a better understanding of the seed ecology of DRF is likely to produce better conservation outcomes.
Since the beginning of 2009 two new seed projects have commenced in Kings Park investigating the seed biology and seed ecology of two critically endangered species; *Commersonia* sp. Mt Groper (Malvaceae) and *Symonanthus bancroftii* (Solanaceae). *Commersonia* sp. Mt Groper has fewer than 80 plants remaining in the wild and is only known from three small isolated remnant patches of bush from the Albany region near the south coast of WA. In comparison, *Symonanthus bancroftii* is a small dioecious shrub known from only one

location near Bruce Rock in the wheat belt, where just two plants (one male and one female) were discovered in remnant bushland in 1996 (male) and 1998 (female) with the female plant subsequently dying in 1999 (after propagation material had been collected). For research purposes, a small quantity of *Commersonia* sp. Mt Groper seeds (136) were collected in December 2009 from the main population (53 plants) while for *Symonanthus bancroftii* several thousand seeds were collected from reintroduced female plants in October 2008 and October 2009. Seed from both species when fresh were found to be highly dormant - the seeds of *C*. Mt Groper were found to possess physical dormancy (i.e. 85 % of seeds were found to have a water impervious seed coat) while seeds of *S. bancroftii* were found to have physiological dormancy (imbibe water readily but 0 % germination when incubated without suitable treatments). Subsequent research has since found that *C*. Mt Groper seeds germinate to around 40 – 60 % (28 days) when seeds are either nicked or exposed to hotwater prior to incubation, while fresh seeds of *S. bancroftii* only germinate when precision nicked (radicle exposed) and treated with 100 ppm GA (81 %), - other treatments assessed (i.e. Kar_1 (Karrikinolide – active compound in aerosol smoke) and dry heat (100 ℃ for 10 mins) proved to be completely ineffective (0 %). The use of nicking and GA *for S. bancroftii* while a good way to illicit germination under laboratory conditions nevertheless does not shed any light on the drivers of dormancy loss under natural conditions. Subsequent experimentation has since found that *S. bancroftii* seeds become Kar_1 responsive during after-ripening though the rate of after-ripening is relatively slow 41 % germination after 12 months in response to Kar_1, 0 % in response to water), while a seed burial trial (still underway) has also confirmed that seeds maintain high viability (90 %) during soil storage for up to 5 months and are also partially Kar_1 responsive leading into their first winter (16 % germination in response to Karrikinolide and 0 % in response to water). Base on these preliminary results it appears that *S. bancroftii* may be a fire ephemeral only recruiting following a bushfire (in response to Kar_1 present in aerosol smoke) following a period of after-ripening in the soil seed bank. Similar soil burial experiments are planned for *C*. Mt Groper when more seeds become available, though the fact that this species has physical dormancy also suggests that it may only recruit following some type of soil disturbance as has been demonstrated with many other species with this type of dormancy. Results for both species suggest that both are *potentially* capable of forming a persistent soil seed bank (to a lesser or greater degree) though the extent and likely longevity are still to be determined. However, other species with similar seed attributes and ecology (physical dormancy and recruitment following fire (fire ephemerals)) have been shown to last for many years (possibly decades) within the soil seed bank suggesting the possibility that if suitable field sites are assessed with the appropriate stimuli recruitment events for both species may still be observed.

Conservation Medicine Initiatives at Perth Zoo - Black Cockatoo Programme

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Participants: DEC; DEC rehabilitators; PZ veterinarians ; PZ veterinary nurses and administrative staff

PZ veterinary staff have provided a veterinary service to Western Australia's Department of Environment and Conservation (DEC) for many years, for the clinical evaluation and treatment of sick and injured wild Black Cockatoos (*Calyptorhynchus* spp.). The importance of this growing relationship was officially recognised in 2006 when a Memorandum of Understanding was drafted to secure an annual financial contribution from DEC to PZ which is used to partly offset staff time and other resources diverted to Black Cockatoo veterinary care.

The partnership between DEC, cockatoo rehabilitators and PZ veterinary staff has resulted in improved success with returning birds to the wild. There has also been a growing recognition of the value of veterinary input into Black Cockatoo conservation efforts. Most recently, a PZ veterinary resident has undertaken a PhD study of conservation medicine aspects of Black Cockatoo rehabilitation and conservation.

The participation of the PZ veterinary team in Black Cockatoo conservation medicine has important indirect benefits. The technical skills acquired by veterinarians and nurses working with large numbers of Black Cockatoos are directly applicable to management of birds in the PZ collection, and the staff derive satisfaction from making a tangible contribution to a local conservation effort. These benefits are important positive outcomes of urban zoo involvement in conservation medicine projects.

Conservation Medicine Initiatives at Perth Zoo – Western Ground Parrot

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As a direct result of the relationships established within DEC through the Black Cockatoo programme, PZ veterinarians were approached at the planning stages of the captive management effort for the endangered Western Ground Parrot. PZ veterinary staff participated in teleconferences, conducted a disease risk analysis, developed biological sample collection protocols, assisted with enclosure design and visited the proposed site to comment on biosecurity management and captive husbandry. PZ veterinarians participate on the WGP steering committee, which answers to the recovery team, and maintain a consultative role with this project.

Conservation Medicine Initiatives at Perth Zoo – Research Opportunities: Australian Sealion tagging and health evaluation

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In 2008, PZ veterinary staff were approached to undertake a pilot project with DEC researchers, anaesthetising male Australian Sea Lions for the fitting of satellite tracking devices. Veterinary aspects of the project included anaesthetic induction and monitoring, biological sample collection, physical examination and health evaluation of the anaesthetised animals. This venture was highly successful in terms of the realisation of the project outcomes, both veterinary and ecological.

Woylie (*Bettongia penicillata ogilbyi*) – research for conservation

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Relisted as *Critically Endangered* by the IUCN Redlist and *Endangered* by the State and Commonwealth, there has been an 80% reduction of the species since 2001. The largest and most important populations have been most affected, generally with 90 - 99% reductions occurring within 3- 5 years. All extant indigenous populations have been affected (i.e. Perup, Kingston, Dryandra and Tutanning) and some of the largest translocated populations (including Batalling, Boyagin, Northern Jarrah forest and Venus Bay Peninsula, South Australia). The declines are continuing in some areas and as yet there have been no clear signs of a sustained post decline recovery. Most of the remaining unaffected populations are small (<300 individuals), isolated and inherently vulnerable.

The species decline was unexpected and followed a successful recovery during the previous 25 years to more than 40,000 individuals, due principally to the successes achieved by fox control and more than 50 translocations across Australia. Several DEC-led investigations of woylies are currently integrated within the collaborative Mesopredator research program: principally focussing on the Northern Jarrah Forest (de Tores et al.), indigenous wheatbelt populations (Marlow et al.) and indigenous forest populations (Wayne et al.). The focus of the former two projects is on interactions amongst predators (i.e. introduced fox and cat, and native chuditch and python) and between predators and native prey such as the woylie. These projects are also integrated components of the Invasive Animals CRC. The latter project (Woylie Conservation Research Project) uses a converse bottom-up approach focussing on woylie demographics, survival and mortality and the key putative agents of decline – predators, food resources and disease. Using Caughley's 'Declining Population Paradigm' as the principal research framework and a comparative population approach, the project involves a large, collaborative, multidisciplinary, interagency research team including Murdoch University, Perth Zoo, Australian Wildlife Conservancy, Department of Environment and Heritage (SA), and University of Western Australia.

While different factors appear to be involved in at least some of the declines, based on current evidence, the leading working hypothesis remains that the mortality driven declines are principally associated with predation/scavenging (particularly by cats) of individuals made more vulnerable by some other factor, principally disease.

Kingston project – responses of terrestrial vertebrates to timber harvesting in the Jarrah forest

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Our current understanding of fauna responses to timber harvesting in the jarrah forest is principally based on two ongoing DEC projects (Kingston and FORESTCHECK) and their closely associated and/or collaborative studies conducted by university students.

The Kingston Project (established 1994) intensively focuses on a single locality and the immediate to short-term responses in real time. FORESTCHECK (established 2001) has a broader spatial and management focus, investigating multiple sites across the jarrah forest and the medium-term responses based on a time-for-space approach (see McCaw and Robinson abstract within). The projects are deliberately complementary and each uses an integrated and comprehensive approach to investigate most flora and fauna taxa in conjunction with other structural and physical ecosystem attributes (e.g. coarse woody debris, soils, etc).

The Kingston Project component investigating the responses of medium-sized mammals is ongoing and includes threatened species such as the woylie (*Bettongia penicillata*; EN), chuditch (*Dasyurus geoffroii*; VU), ngwayir (western ringtail possum, *Pseudocheirus occidentalis*; VU), and wambenger (brushtail phascogale, *Phascogale tapoatafa ssp.*; VU), also the priority listed quenda (*Isoodon obesulus fusciventer*), and 'near threatened' koomal (common brushtail possum, *Trichsurus vulpecula hypoleucus*). Bats, including the priority listed western false pipistrelle (*Falsistrellus mackenziei*), are currently being investigated by means of a PhD project (P. Webala, Murdoch University).

The woylie, chuditch and quenda were not apparently negatively impacted by timber harvesting. Koomal abundances respond negatively to logging and demonstrate that habitat trees and unlogged buffers are particularly important in mitigating these effects. Spotlighting evidence demonstrates that koomal remain abundant across the landscape in the presence of contemporary and recent logging. Ngwayir survivorship was reduced by at least 40% by the harvesting and extraction alone: principally due to an increased vulnerability to predation. Spotlighting evidence indicates a population collapse to undetectable levels after harvesting disturbance across the Greater Kingston area (including logged and unlogged forest). Ngwayir abundance in the Upper Warren region was negatively related to logging and fire intensity and age, and extent of fragmentation by agriculture. It was also positively related to fox control. The identification of the attributes selected for in diurnal den trees by both possums also inform the refinement of silvicultural guidelines for the selection and retention of habitat trees.

The potential impacts of climate change and land transformation on biodiversity in Mediterranean climate south-west Western Australia – implications for threatened species conservation

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Widespread land transformation, associated habitat fragmentation, invasive species and introduced diseases continue to drive substantial declines in biodiversity in Mediterranean climate south-west Western Australia (SWWA). Projected climate change may interact with these factors to further threaten biodiversity. Mean annual temperatures have increased and since the 1970's there has been a significant decline in autumn and early winter rainfall and reduced stream flow. The consensus among Global Climate Models is that temperature will continue to increase and rainfall will continue to decline in the SWWA.

Patterns of biodiversity in SWWA are strongly influenced by climate. Unlike the other Mediterranean climate regions of the world SWWA is of low relief and with the exception of the Stirling Ranges which are just 1109 m a.s.l., there is limited scope for altitudinal migration into cooler and moister montane refuges. Under projected climate change, warmer and more arid conditions are expected to shift southwards and westwards, and there is a possibility that the coolest and wettest climate zones on the south coast, containing many relictual and mesothermic phylogenetic lineages may disappear. Where the latitudinal extent of the continent permits shifts in geographic range, extensive land transformation for agriculture and urbanization will limit the amount of habitat available for colonization, and habitat fragmentation will restrict dispersal.

As a first step in assessing the vulnerability of SWWA's biodiversity to climate change we have modeled the potential impacts of three climate change scenarios and their interaction with land transformation on the ecogeographic domains of regional biomes, endemic plant species (*Banksia* spp.) and the threatened

marsupial quokka (*Setonix brachycurus*). The models predict that the combined effects of climate change and land transformation may have significant adverse impacts on biodiversity, increasing the number of threatened species in the region with one regional biome the karri forest potentially losing all suitable climate range, 66% of *Banksia* spp. and quokka losing greater than 80% of their range by 2070 under the high emissions scenario. These results need cautious interpretation in light of the many assumptions and uncertainties in the climate and ecological models used. Nevertheless, the potential impacts identified provide insights into the relative sensitivities of regional biomes to projected climate change, indicate that increasing number of threatened species are likely, highlight the need for a better understanding of physiological and climate thresholds and ecological monitoring to detect change, and stress the importance of ecological restoration and identification and management of climate refuges as adaptation actions.

Managing South-Western Australia's threatened species in an era of global change

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Threatened plant species in SWWA are subject to multiple threatening processes which operate across ecological scales. Research investigating the effects of threatening processes on population viability provides guidance for determining priority actions for recovery, translocation and ongoing conservation management of threatened plants. The following provides a summary of key findings relevant to management. Contrary to expectations, many threatened SWWA plant species investigated to date have pollination and mating systems that allow them to produce fit offspring in small isolated population fragments. Despite this, populations remain at risk of extinction from demographic and environmental stochasticity. In such cases managing persistence (hydrology, fire) and regeneration (fire, weeds), and undertaking translocations will be more important than increasing connectivity among landscape fragments.

Investigations of threatened plants endemic to granite outcrops show that populations are stable provided adult plants are protected from factors which increase the risk of mortality, in this case livestock grazing and fire. Remarkably, extant populations have persisted on the same outcrops since the early Pleistocene (1 to1.5 Mya), a period of extraordinary climate dynamism, giving some hope that the climate tolerances of species may be broader than their present geographic distributions indicate.

The co-incidence of multiple threatening processes and limited management options may make *in situ* conservation intractable for some species. In the Stirling Range National Park, 12 threatened plant taxa are restricted to the mountain peaks. The pathogen *Phytophthora cinnamomi* has become prevalent in the montane environment causing widespread mortality among endemic species such as *Banksia montana*. Two wildfires killing many plants and low rates of seedling replacement have further reduced the viability of the population. Projected climate change may place further stress on montane species. Ecological monitoring precipitated *ex situ* conservation measures for *B. montana* that at least provide some insurance in the near term, but options for conservation in the wild remain limited.

Management of threatened species must recognize that threatening processes are often interactive and multi-scalar. Rapid climate change is a new stressor on biodiversity and conserving threatened species will become an even greater challenge.

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