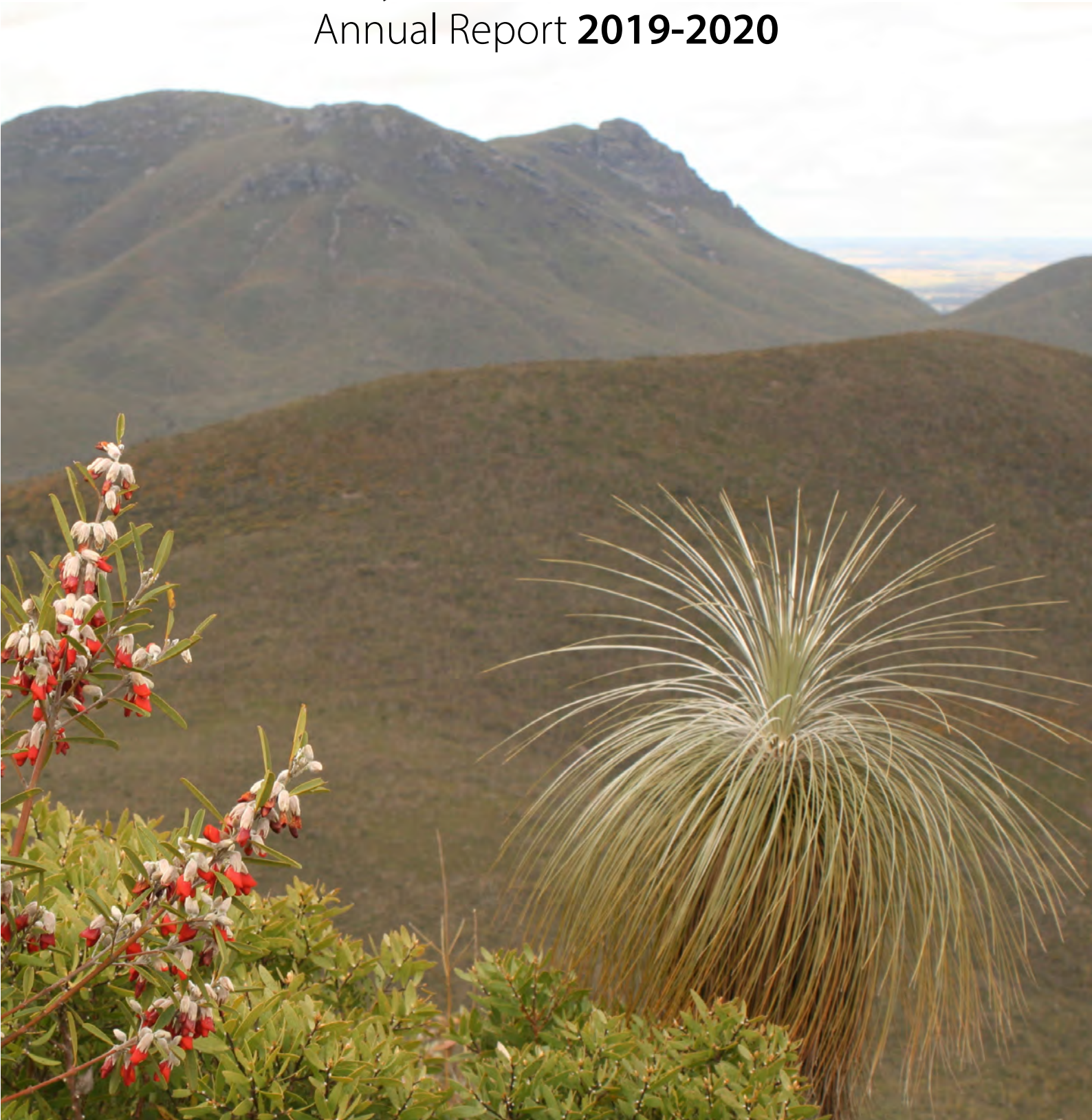


Department of **Biodiversity,  
Conservation and Attractions**



**Biodiversity and  
Conservation Science**

# Biodiversity and Conservation Science Annual Report **2019-2020**



## **Acknowledgements**

This report was prepared by the Department of Biodiversity, Conservation and Attractions (DBCA).

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The recommended reference for this publication is:  
Department of Biodiversity, Conservation and Attractions, 2020,  
*Biodiversity and Conservation Science Annual Report 2019-20*,  
Department of Biodiversity, Conservation and Attractions, Perth.

## **Images**

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Mollerin Rock reserve. *Photo – Val English/DBCA*

Shark Bay bandicoot. *Photo – Saul Cowen/DBCA*

Shark Bay seagrass. *Photo – Luke Skinner/DBCA*

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Post fire monitoring. *Photo – Lachie McCaw/DBCA*

Kalbarri yellow bells. *Photo – Kelly Shepherd/DBCA*

Western grasswren. *Photo – Saul Cowen/DBCA*

Dragon Rocks *Kunzea*. *Photo – Kelly Shepherd/DBCA*

**Department of**  
**Biodiversity, Conservation and Attractions**  
Biodiversity and Conservation Science  
Annual Report  
**2019–2020**



Department of **Biodiversity,  
Conservation and Attractions**



**Biodiversity and  
Conservation Science**

# Director's Message

I am pleased to present our Biodiversity and Conservation Science report for 2019-20 as we continue to deliver on the government's commitment to build and share biodiversity knowledge for Western Australia. Our Science Strategic Plan and Program Plans articulate how our work contributes to delivery of the biodiversity science priorities for the State as the knowledge generated by our science is essential to ensure we conserve and value add to the unique biodiversity we have around us.

I acknowledge the start of 2020 presented unforeseen challenges due to the coronavirus global pandemic. While some field work was disrupted by the travel restrictions, we maintained delivery of a high level of quality science to inform conservation management. I thank all our Biodiversity and Conservation Science staff for their perseverance during this disrupted time.

We have continued the renewal of our capability to provide innovative science that informs current and future conservation initiatives. The strength of Biodiversity and Conservation Science resides in our people, and in the past year we have welcomed new staff with expertise in ecosystem genomics, wetland ecology, community ecology, plant genetics, water monitoring, conservation policy and species management.

2020 is the 50<sup>th</sup> anniversary of our Herbarium journal *Nuytsia* and we are celebrating with the publication of names and descriptions for 50 new plant species throughout the year. Other highlights of our scientific research includes emergency actions and monitoring to manage the impacts of bush fire on western ground parrot in Cape Arid National Park and on threatened plants and ecological communities in the Stirling Range National Park, implementation of water quality monitoring in the Swan-Canning river system, a survey of Lake Carnegie to inform identification of conservation values, temporal analysis of seagrass extent and response to a marine heatwave for the Shark Bay World Heritage Area, analysis of long term thinning experiments to inform forest management, and the first bandicoot born on Dirk Hartog Island following translocation. The great science work we undertake is facilitated by the excellent support of our administration staff.

As we continue to deliver excellent science to underpin effective biodiversity conservation in Western Australia we look to new opportunities. The Premier announced \$7.7 million funding for the Biodiversity Information Office (BIO) to be established in DBCA and support the broader Environment Online initiative in partnership with the Commonwealth Digital Environmental Assessment Project. BIO will collate, curate, and make available biodiversity data to provide key information to support environmental management and conservation in Western Australia. I look forward to delivering on this exciting initiative in the coming years. We remain active in pursuing opportunities and seeking innovative ways for delivering science to support conservation, and we continue to communicate our scientific outputs and outcomes to a diverse range of audiences through a variety of avenues, including scientific papers, technical and popular articles, social media, conference talks, seminars and other presentations.

I am pleased that we continue our effective partnerships with conservation staff in the Parks and Wildlife Service, Kings Park and Botanic Garden, Perth Zoo and the Rottnest Island Authority. We continue to engage with a wide range of external partners at universities, CSIRO, NGOs, WABSI, WAMSI and the NESP Threatened Species Recovery and Northern Australia Environmental Resources hubs. We continue to have a large number of active science partnerships and our scientists are involved in co-supervision of many Honours, Masters and PhD students.

I look forward to continuing to work effectively with all our partners to deliver excellent science that informs conservation and management of our diverse plants, animals and ecosystems, and supports effective management of our parks and reserves, delivery of our fire program and engagement of visitors with our natural attractions.

Dr Margaret Byrne  
Executive Director, Biodiversity and Conservation Science  
November 2020

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## Service Delivery Structure

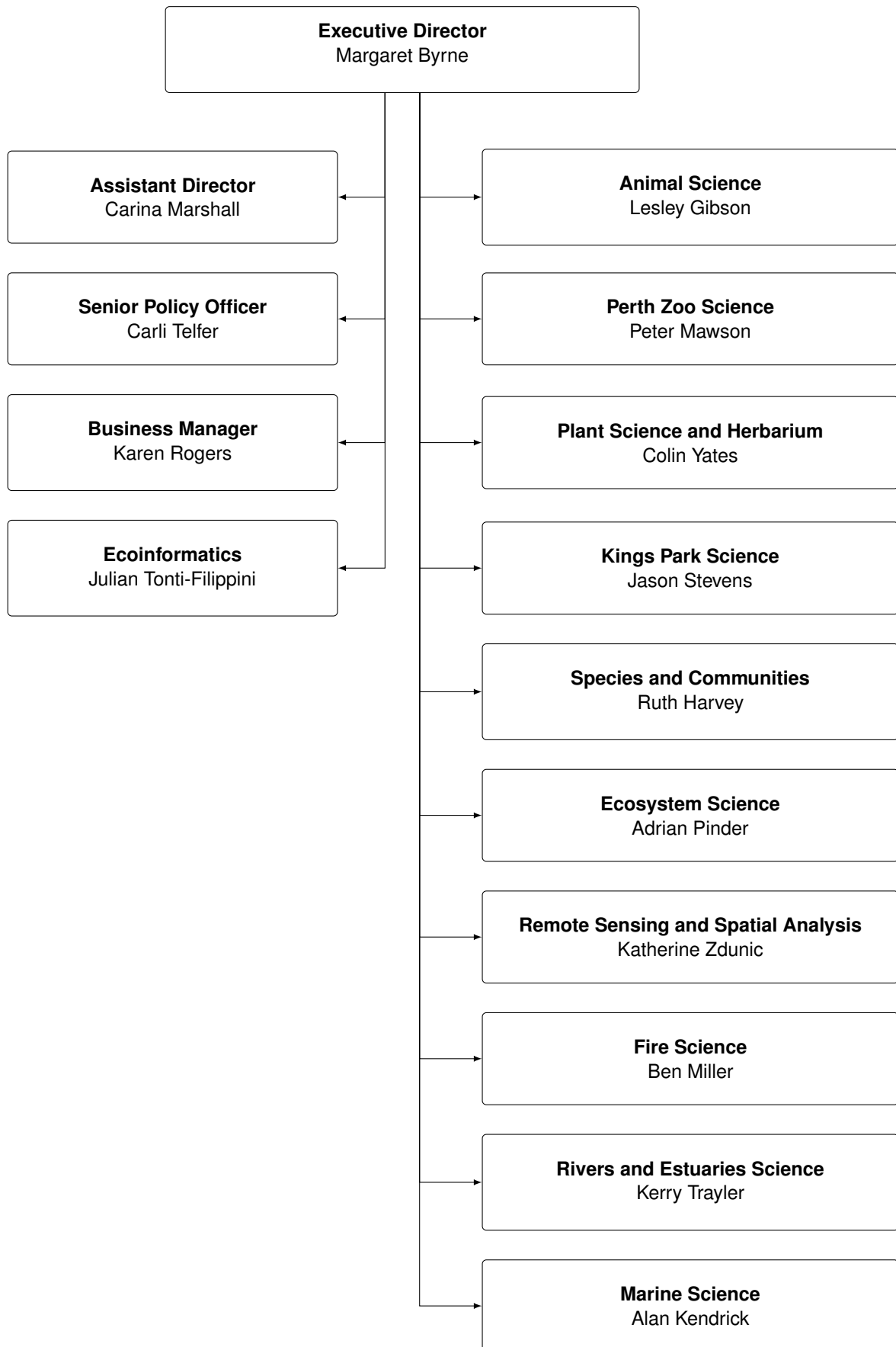
Science in the Department of Biodiversity, Conservation and Attractions is undertaken in accordance with the departmental Science Policy, where science refers to scientific research, scientific monitoring and science communication undertaken in relation to the biological, physical and social environments.

Biodiversity and Conservation Science coordinates and delivers science in the Department of Biodiversity, Conservation and Attractions, providing science and biodiversity knowledge to support the functions of the Parks and Wildlife Service, Botanic Gardens and Parks Authority, Zoological Parks Authority and Rottnest Island Authority.

Biodiversity and Conservation Science is structured into programs focused on key themes for the delivery of targeted science to support evidence-based decision making and the conservation and land management functions of the department. Science and research is undertaken using both Western Australian Government and external funding sources.

Biodiversity and Conservation Science operates from a range of locations including Kensington, Kings Park, Perth Zoo, Woodvale, Manjimup, Bunbury, Busselton, Kununurra, and Albany, and includes the Western Australian Herbarium.

Biodiversity and Conservation Science staff have expertise in animal biology, animal breeding, aquatic ecology, biological survey, collections management, conservation biotechnology, conservation genetics, conservation medicine, conservation policy, ecology, ecological restoration, ecoinformatics, ecophysiology, fire behaviour, hydrology, marine biology, plant biology, remote sensing and spatial analysis, seed biology, systematics and taxonomy.





## Animal Science

**Program Leader: Lesley Gibson** Applied research undertaken by the Animal Science Program seeks to understand the factors and processes that are critical for the conservation of Western Australia's rich and unique native fauna. The major objectives of the program are to ensure the persistence of threatened species through local and landscape-scale management actions, including reducing key threats such as predation by foxes and feral cats, inappropriate fire regimes, competition and predation by introduced rodents on islands, as well as assessing cane toad impacts and reconstructing the fauna of rangeland and arid areas.



### **Structured decision making for optimal feral herbivore management for biodiversity conservation in the Kimberley**

SP 2019-069

MD Barnes, J Kinloch

#### **Context**

Threatened species have variable exposure and susceptibility to threats, and responses to management. Feral herbivore control is a cost-effective threat management strategy for conserving many threatened and endemic species in the Kimberley, particularly its small mammal fauna, and comprises a large part of the Kimberley work program. The efficiency and cost-effectiveness of this program could be increased by impact-focused spatial action planning, to identify efficient spatially explicit management strategies that balance the conservation needs of multiple species while accounting for other funds and opportunities in that timestep.

#### **Aims**

- Apply structured decision making collaboratively with stakeholders to identify cost-effective feral herbivore control strategies.
- Evaluate the costs and benefits of existing and proposed herbivore control strategies.
- Understand and characterise synergies and trade-offs among alternative management strategies for herbivore control.

#### **Progress**

- Collaborative problem formulation is underway with the Kimberley Region.

- Feral herbivore data has been sourced from the Kimberley Region for the Ord River and Kurriji Pa Yajula Nature Reserves, Walyarta, Miluwindi and Purnululu Conservation Parks, Mitchell River, Prince Regent and Drysdale River National Parks and the Ord River Regeneration Reserve.
- Spatial analysis is underway.
- Species distribution models of threatened fauna species have been acquired from the NESP Northern Australia Environmental Resources Hub and are under review.

### Management implications

- The project is utilising information and knowledge from recent annual control programs to identify feral herbivore hotspots and their likely impacts on threatened species. Identification of these hotspots will inform the development of future cost-effective feral herbivore control programs with targeted strategies for key reserves that maximise the benefits for key conservation values and increase efficiency.

### Future directions

- Undertake regional workshops.
- Complete spatial modelling and trade-off analysis.



### Structured decision making for translocation

SP 2019-067

MD Barnes, L Gibson, JM Renwick, S Cowen, C Sims, A Wayne

### Context

Translocation is a valuable conservation tool that can yield significant benefits and can sometimes be costly and high risk. Decisions on translocations include thorough consideration of potential benefits, weighed against costs and risks of the translocation and alternative options. Western Australia is at the forefront of translocations in Australia and has a number of translocation programs identified for implementation over the next five years. Other States and Territories are also using translocation as a conservation tool and the number of requests to source species from Western Australian populations is increasing, and requires consideration of both source populations and release locations. It is important that these translocations maximise conservation outcomes for the species, without detrimental consequences for source populations and that the cost is proportional to the benefit. A strategic process for making translocation decisions that captures all available information relevant to any proposed translocation and accounts for uncertainty will support enhanced and transparent decision-making under risk and uncertainty.

### Aims

- Develop a framework to support decision making for animal translocations.
- Evaluate the costs, benefits, and risks of proposed translocations, to ensure efficiency, mitigate risks to source populations, and support decision-making that is robust to uncertainty in future conditions.

### Progress

- Rapid prototyping, problem formulation, objectives and metrics selection, and alternatives development completed for all case studies (Dirk Hartog Island (DHI) translocations, woylie and boodie).
- Sign diagraph network modelling undertaken to evaluate the influence of order, location and size of translocations on the risk of extirpation of target species on Dirk Hartog Island.
- Structured decision-making and IUCN translocation guidelines used to inform revised population management strategy for woylies.
- Live, current, annually updated, widely accessible data documenting status and condition of woylie populations identified as a key need for effective evidence-informed evaluation.

- Population modelling underway for both woylies and boodies.
- Rapid prototyping completed for boodies and reported to Shark Bay mammal recovery team.
- Alternative management strategies developed for boodies incorporating recent genetic findings.

### Management implications

- A robust and transparent process that supports decision-making allows for an assessment of the value of the translocation for improved species conservation outcomes, relative to the potential impact and cost of harvest for source populations.
- An evaluation method that allows a comparative assessment of translocations will assist with sequence of harvest and meeting demands for translocation requests.
- The use of the framework and products produced in this project will result in reduced risks, improved success outcomes for translocations, and increased efficiency in setting and evaluating objectives, and delivering conservation outcomes.
- Given that variation in translocation order (i.e. sequence of species released) and timing on DHI had limited influence on predicted success, the project can proceed with greater confidence and flexibility with respect to the strategy used, and the order of translocations on DHI can be revised to accommodate logistical concerns and species availability with low risk of compromising species outcomes.
- Translocations of heath mouse, greater stick-nest rat and dibbler were predicted to be at greater extinction risk on DHI than other taxa, therefore additional monitoring or contingencies may be required.

### Future directions

- Publish network model findings.
- Undertake population modelling for boodies and woylies.
- Develop a strategic framework for animal translocation decision making.



## Conservation of the night parrot

SP 2017-036

A Burbidge, N Hamilton

### Context

The critically endangered night parrot has been confirmed breeding in only two locations - one in Queensland and one in Western Australia. The night parrot has not been adequately surveyed across much of its potential habitat, and a lack of knowledge of foraging and roosting habits has hampered progress in understanding the ecology of the species. This constrains possible recovery actions and management relating to resource development proposals. Identifying the conservation requirements of the night parrot is essential for informed management of this poorly known species.

### Aims

- Assess the spatial extent of the population in Matuwa/Lorna Glen and surrounding areas, and subsequently the entire Lake Carnegie catchment.
- Determine where the birds are foraging by identifying vegetation types they are using and the spatial relationship between roosting and foraging habitat.
- Determine differences in the vegetation at occupied versus non-occupied roost sites and foraging sites to inform predictive models.
- Engage with Traditional Owners to encourage survey for night parrots and sensitive management for the species.

## Progress

- Audio recording units have been deployed in known or suspected night parrot habitat at several locations, including in the Carnegie catchment, to detect calls.
- Analysis of audio files has commenced, but is constrained by a lack of robust software recognisers, which have proven difficult to construct for this species.

## Management implications

- Documentation of known night parrot calls will improve survey and monitoring for the species and facilitate a better understanding of their distribution and conservation status.
- Information on distribution will guide conservation management and assessments of the impacts of resource developments on the species.

## Future directions

- Investigate development of robust software recognisers for call analysis.



## Understanding and reducing python predation of the endangered Gilbert's potoroo

SP 2017-001

D Pearson, S Hill

## Context

Carpet pythons are predators of a range of threatened mammal fauna, including the critically endangered Gilbert's potoroo (*Potorous gilberti*). Python predation can reduce adult survival and curtail recruitment. Current 'predator proof' fences, while effective at reducing or eliminating predation by foxes and feral cats, are likely to have little or no effect on levels of python predation.

Python predation has been identified as a significant threat to the Gilbert's potoroo population in the Waychinicup National Park enclosure. In a review of options following the 2015 fire that impacted the only known wild population at Two Peoples Bay, it was considered that management intervention is required to reduce python predation of potoroos within the enclosure. It appears that python predation is limiting population growth and hence the production of individuals for translocation.

## Aims

- To determine the most effective ways to locate and remove carpet pythons from within and around Gilbert's potoroo populations and so reduce the current level of predation of this critically endangered mammal.

## Progress

- Techniques to locate and capture pythons in the Waychinicup enclosure were reviewed over the entire study. Radio-tracking males during the breeding season proved to be the most successful of the seven techniques trialled, resulting in about 40 percent of captures. It was the most successful technique for locating adult female pythons, the cohort most responsible for observed potoroo predation.
- Eight adult females were relocated to other areas of Waychinicup National Park and did not return to the enclosure area.
- All but one of the eight telemetered male pythons were regularly located outside the enclosure after the breeding season. This suggests they prefer structurally diverse coastal heathland on foredunes to more open shrubland inside the enclosure. This observation along with their smaller size relative to adult females, suggests that male pythons pose little or no threat to Gilbert's potoroo.



## Management implications

- Carpet pythons are clearly significant predators of Gilbert's potoroo and appear to be constraining the growth of the population in the Waychinicup enclosure, and by inference, the recovery of the wild population on Mt Gardner.
- Timing searches at the right time of year (python mating season, mid-October to mid-November) and radio-tracking are the best ways to locate and remove pythons.
- Carpet pythons move easily through or over the enclosure fence so the python population around the enclosure also needs to be managed.
- Ongoing removal of adult female carpet pythons from the Waychinicup enclosure is likely to improve survival and recruitment of Gilbert's potoroo.

## Future directions

- Continue to locate male carpet pythons to find and relocate further female pythons.
- Searching for, radio-tracking and removing pythons on Mt Gardner to improve the survival chances of the few potoroos remaining there.



## South West Threatened Fauna Recovery Project: Southern Jarrah Forest

SP 2016-068

A Wayne, M Maxwell, C Ward

## Context

The primary goal of the South West Threatened Fauna Recovery Project (SWTFRP) is to contribute to the recovery of key threatened mammal and bird species at four key sites in south-western Western Australia, through integrating feral cat baiting with existing introduced predator control programs, undertaking monitoring of threatened species and translocations to supplement and establish new, secure populations where necessary. The key sites selected were South Coast reserves, Upper Warren reserves, Dryandra Woodland and Kalbarri National Park.

This project is a component of the SWTFRP, focussing on the southern jarrah forest, which is an important area for the conservation of several mammal and bird species threatened by introduced predators. To date there has been no effective cat control within the southern jarrah forest, including the priority conservation areas within the Upper Warren region. *Eradicat*® presents an opportunity for developing an important tool within an effective cat control program that is essential to the long-term conservation of imperilled fauna threatened by introduced predators.

## Aims

- To recover wild populations of western ringtail possums, woylies and numbats in the Upper Warren area, through developing effective integration of feral cat control with existing fox control in the southern jarrah forest.
- Identification of the efficacy of *Eradicat*® baiting according to current operational delivery methods (aerial and ground) and time of year.
- Quantification of the risk to potentially vulnerable non-target native mammals in the southern jarrah forest to operational use of *Eradicat*®.
- Improve live capture of feral cats in the southern jarrah forest by minimising non-target captures.
- Engaging effectively with neighbours about the control of introduced predators and the recovery of native species.

## Progress

- A paper describing some of the results from the stage 1 study was submitted to *Wildlife Research* and is currently in review. This work provides recommendations for improvements within an integrated and holistic invasive animals management framework to deliver better biodiversity conservation outcomes.

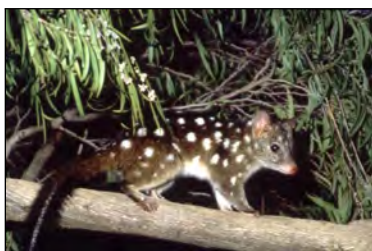
- There were no significant differences in encounter rates or bait removals by cats or foxes immediately after autumn burns compared with unburnt reference sites. However, having the baits on forest tracks compared with 5-20 m off track can substantially improve cat and fox encounter rates and baiting opportunities.

### Management implications

- Controlling feral cats in the southern jarrah forest is challenging. The effectiveness of *Eradicat*® baiting using existing protocols has been demonstrated and provides clear direction on how further improvements can be made.
- The *Eradicat*® baits can be effective at controlling foxes, and are a low risk to vulnerable species, such that they can complement other methods.
- Feral cat baiting is most effective when conducted within an integrated and holistic invasive animal management system.
- Improved understanding of the distribution, occupancy, species richness, and spatial and temporal activity patterns can directly inform management and conservation planning and operations. For instance, it helps identify areas of high conservation value and hotspots of introduced species to be considered during planning for timber harvesting, burning, introduced predator control, and other disturbance activities.
- This study demonstrates the substantial benefits of having a regional-scale survey and monitoring program that is appropriately designed to identify fauna responses to management and conservation activities and spatio-temporal, environmental and population changes.

### Future directions

- Complete bait uptake trial data analysis and manuscripts for publication, including bait longevity, non-target bait interactions, and spatial ecology of feral cats.



## Dirk Hartog Island National Park Ecological Restoration Project – fauna reconstruction

SP 2016-030

S Cowen, C Sims, L Gibson, K Ottewell, S Garretson, K Rayner, J Angus, A Burbidge

### Context

The Dirk Hartog Island National Park Ecological Restoration Project aims to restore the ecological condition of Western Australia's largest island to that seen by Dirk Hartog when he landed on the island in 1616. Establishment of populations of 12 mammal and one bird species on Dirk Hartog Island (DHI) over a 12 year period is a key part of this project. Of these species, four are listed as endangered and six as vulnerable under the national *Environment Protection and Biodiversity Conservation Act 1999*, and their successful re-establishment will contribute towards improving the conservation status of these species. The translocation of 13 native species to an island 633 square km in area, makes it the largest fauna reconstruction project in Australia and one of the largest in the world. To allow this to proceed, sheep, feral goats and feral cats have been removed and the eradication of feral cats represents the largest eradication program achieved globally. Genetic information on source populations is being used to inform founder selection, genetic monitoring of released animals, and ongoing management practices.

### Aims

- Identify the most suitable source populations to act as founders for new populations on DHI, using the criteria set out in the *Dirk Hartog Island National Park Ecological Restoration Strategic Plan*.
- Establish new populations of 12 mammal species and one bird species on DHI, using the species selection criteria set out in the Strategic Plan.
- Confirm that the translocations are successful and that all new populations on DHI are healthy and self-sustaining, using criteria set out in the Strategic Plan and approved translocation proposals.

- Promote scientific research associated with the translocations, monitoring and establishment of fauna, and publish scientific findings.

### Progress

- Translocations of 50 rufous hare-wallabies and 72 Shark Bay bandicoots from Bernier and Dorre Islands and 26 dibblers from a captive-breeding program at Perth Zoo were undertaken.
- Translocated populations of banded and rufous hare-wallabies have established in the areas they were released in 2017 and 2018 and appear to be increasing in abundance.
- A genomic analysis of island and mainland populations of rufous hare-wallaby to assess the outcomes of mixing Bernier and Dorre Island rufous hare-wallabies on DHI has been completed.
- Harvesting scenarios for Bernier and Dorre Island banded hare-wallabies have been completed in collaboration with UWA.
- Effectiveness of faecal DNA analysis for monitoring hare-wallabies has been assessed.
- All 12 radio-collared Shark Bay bandicoots remained alive after four to seven weeks of tracking and had improved or maintained condition. Reproductive activity was evident with juveniles also observed on camera, and the first island-born bandicoot captured.
- Results of captive trials to optimise collar-fit on the bandicoots has been accepted for publication in *Australian Mammalogy*.
- Radio-tracking of dibblers was unsuccessful and a collaring trial is now underway to improve this technique for future releases.
- Source population monitoring of dibblers on the Jurien Bay islands revealed relatively low numbers, though breeding activity was observed.
- Captive breeding at Perth Zoo continues, with 11 males and 10 female dibblers available for breeding.
- Analyses on island, mainland and captive populations of dibbler to investigate genome-wide diversity and impacts of genetic mixing in reintroductions are underway.
- Population genomic analysis of all wild and reintroduced populations of boodies is well-progressed and will inform the choice of source populations for reintroduction to DHI.
- Captures of western grasswrens at Hamelin Reserve and Francois Peron National Park were undertaken to collect genetic samples and band birds to inform a translocation strategy for this species.
- A genomics project is currently underway to investigate the genetic diversity of Shark Bay mouse populations on Bernier, Northwest and Faure Islands, in collaboration with Australian Wildlife Conservancy.
- Monitoring of small extant vertebrates on DHI showed a significant increase in populations of native sandy inland and ash-grey mice.
- The Wildlife Population Health residency position with Murdoch University has begun work on developing a disease risk analysis for extant rodents.
- Vegetation plot monitoring on DHI continued, including soil sampling, and collection of imagery using a remotely-piloted aircraft.

### Management implications

- The successful translocation and establishment of sustainable populations of banded and rufous hare-wallabies, Shark Bay bandicoots and dibblers on DHI is likely to improve both their conservation status and improve ecosystem function on DHI.
- The development of innovative and non-invasive approaches to effectively monitoring fauna species will provide an effective solution that can be implemented to reduce time in the field and with no requirement for Animal Ethics Committee approval.
- Genomics analysis informs population management strategies and provides a suite of novel, affordable monitoring tools to ensure ongoing adaptive management of these populations.

### Future directions

- Further supplementation translocations of Shark Bay bandicoots and dibblers are scheduled for spring 2020 and the first releases of greater stick-nest rats and Shark Bay mice are planned for autumn 2021, pending all relevant approvals.
- Population genomic analyses on dibblers, banded hare-wallabies and Shark Bay mouse will be progressed. High-throughput SNP arrays will be developed and validated for genetic monitoring of banded and rufous hare-wallaby, Shark Bay bandicoots and dibblers.



## Improved fauna recovery in the Pilbara – benefitting the endangered northern quoll through broad-scale feral cat baiting

SP 2015-016

R Palmer, H Anderson, B Richards

### Context

The northern quoll (*Dasyurus hallucatus*) is one of a suite of terrestrial mammal species that has declined in the Pilbara over the last 100 years. Predation by feral cats is a key threat to this endangered species. The development of the *Eradicat*<sup>®</sup> feral cat bait has provided the opportunity to control this invasive predator at a landscape scale in the south-west of Western Australia but questions remain as to the potential risks of broad-scale feral cat baiting programs on northern quolls and other native carnivores in the Pilbara. A trial baiting program undertaken on the Yarraloola pastoral lease in 2015 demonstrated that the *Eradicat*<sup>®</sup> bait presents no detectable risk to northern quolls. Based on this evidence, annual winter baiting of feral cats with *Eradicat*<sup>®</sup> over 145,000 hectares of Yarraloola will occur from 2016 to 2019. Monitoring programs will measure its success in reducing cat numbers and the response by northern quolls.

### Aims

- Conduct a broad-scale aerial baiting program using *Eradicat*<sup>®</sup> to target feral cats on Yarraloola.
- Assess the effectiveness of broad-scale aerial baiting program using *Eradicat*<sup>®</sup> to target feral cats on Yarraloola.
- Assess the potential benefits of broad-scale cat baiting on northern quoll populations by comparing their abundance and demographics over time within the baited Yarraloola site with the neighbouring unbaited reference site on Red Hill pastoral lease.

### Progress

- Another year of camera monitoring was undertaken on Yarraloola (baited) and Red Hill (reference site) before and after aerial baiting using *Eradicat*<sup>®</sup> to monitor changes in feral cat occupancy.
- Detection rate of feral cats on camera traps declined by 34 percent following baiting and 33 percent of radio-collared feral cats died. Two collared feral cats that survived baiting in 2018 when conditions were good, died following baiting in 2019 when conditions were much drier.
- Monitoring of northern quoll populations at both Yarraloola and Red Hill showed that capture rates of quolls continued to be higher in the feral cat-baited cell, but were lower than 2018.
- Increased detection of quolls on camera trap arrays used for feral cat monitoring indicate an ongoing expansion of their habitat occupancy in response to feral cat control. However, predation rates by feral cats were high with 20% of feral cat scats containing quoll remains. A collapse in rodent populations due to the dry conditions was the likely cause of this dietary shift by feral cats.

### Management implications

- The evidence that *Eradicat*<sup>®</sup> baiting has no harmful impact to northern quolls indicates that quolls benefit both directly and indirectly from landscape level control of feral cats and that operational use of the *Eradicat*<sup>®</sup> feral cat bait in the Pilbara can protect northern quolls and other native fauna from feral cat predation.

### Future directions

- Finalise the project and publish the outcomes.
- Provide recommendations regarding the registration of *Eradicat*<sup>®</sup> feral cat baits for operational use in areas where northern quolls are present.



## Monitoring of threatened birds on Dirk Hartog Island

SP 2013-021

A Burbidge

### Context

This project was designed to develop and implement a monitoring program for the three extant threatened bird species on Dirk Hartog Island (DHI): DHI southern emu-wren, DHI rufous field-wren, and DHI white-winged fairy-wren. This project is part of the broader Dirk Hartog Island National Park Ecological Restoration Project. The intent is to allow assessment of the distribution, status and population trends of the threatened bird species, and enable monitoring of change in relation to management actions aimed at restoring the island's plant and animal communities to a state similar to that which existed before pastoralism and the introduction of exotic weeds, herbivores and carnivores.

### Aims

- Determine historical and contemporary occurrence of threatened bird species across Dirk Hartog Island.
- Model and map occurrence of each species across the island in relation to vegetation characteristics.
- Develop a robust monitoring program.
- Clarify the conservation status of each of the threatened bird taxa.

### Progress

- Analysis of variation in fieldwrens indicates that the currently recognised subspecies on Dirk Hartog Island and Bernier Island are not valid.
- A paper describing genetic, morphological, plumage and vocal variation across the range of the species has been prepared and will be submitted for publication.

### Management implications

- Both the Dirk Hartog and Bernier Island fieldwren subspecies should be removed from the list of threatened species.
- As all three threatened taxa are more abundant and widespread on the island than previously thought, localised management actions will have only limited impacts, and monitoring will not need to be done as frequently or as intensively as previously anticipated.

### Future directions

- Publish accounts of the modelling of species distribution across the island, and the population estimates of the species.
- Establish an optimal monitoring design for each species across the island.



## Improving the use of remote cameras as a survey and monitoring tool

SP 2013-005

M Cowan

## Context

The use of camera traps is often regarded as an effective tool for fauna survey and monitoring with the assumption that they provide high quality, cost effective data. However, our understanding of appropriate methods for general survey and species detection, particularly in the small to medium sized range of mammals, remains poorly understood. Within the department, the use of camera traps to date has usually been restricted to simple species inventories or behavioural studies and beyond this there has been little assessment of deployment methods or appropriate analytical techniques. This has sometimes led to erroneous conclusions being derived from captured images. Camera traps have the potential to offer a comparatively reliable and relatively unbiased method for monitoring medium to large native and introduced mammal species throughout the state, including several significant cryptic species that are currently not incorporated under the Western Shield fauna monitoring program. Research is required to validate and test different survey designs (temporal and spatial components) and methods of deploying camera traps, and to interpret the results in a meaningful way. Work is needed to determine how best to use remote cameras to provide rigorous data on species detectability, and species richness and density.

## Aims

- Investigate methodologies for the use of camera traps to examine the temporal and spatial occurrence of native and introduced mammal species in the south-west of Western Australia.
- Investigate and assess the most appropriate methods of image analysis and data storage.
- Develop analytical tools for interpretation of camera trap data.
- Run comparative trials on new models of cameras and trapping array designs to assess effectiveness and suitability for different monitoring and survey programs.

## Progress

- An R program for analysing camera trap data has been further refined allowing web-based export of data and graphics, improved data interrogation tools, graphical presentation of multivariate analysis, species accumulation plots, individual species activity patterns and password security.
- Analysis of camera trap data for over twenty projects across five DBCA regions is being undertaken through the web-based application.
- Interrogation of the Dryandra dataset (over 250,000 mammal detections) continues to inform DBCA staff on appropriate methods and issues for camera trap data analysis.
- Advice on the optimal design of camera trap arrays was provided.

## Management implications

- Assessment of variation in detection rates over time for all critical weight range species from this project is providing essential data on population stability and trends, and the effectiveness of control measures on introduced predators.
- The camera array at Dryandra now forms a reference location against which other sites can be compared in relation to management actions.
- It appears that detection rates for the majority of the 13 target species monitored at Dryandra are significantly correlated with ambient temperatures. Winter months have been shown to have the highest detection rates apart from one species, the numbat, which has increased detection during hotter conditions. This has implications for the use of cameras in that surveying in warmer months may require increased effort to produce similar results to cooler times and monitoring data under warm conditions may result in a perceived reduction in relative abundances when compared to cooler periods.
- Careful consideration is essential in regard to the specific species being targeted, questions being addressed, and type of camera trap utilised. Survey design considerations include camera setup for target species, timing (especially if repeat sampling for detection rates e.g. monitoring), duration, camera numbers, camera spacing, logistics of implementing field components and skills and expertise to identify, manage and analyse data.
- Reconyx camera traps have been among the most effective and reliable commercially available models for departmental requirements and the current model, HP2X, is recommended for use, though differences in model performance may have ramifications for comparative data.

## Future directions

- Continue to assess improvements and changes in camera trap technology against benchmark sites and camera models to help inform best practice.
- Further refine the software application for camera trap data analysis including a standalone package that can be distributed more broadly.
- Compare conventional trapping data using Western Shield information to that from cameras over the same timeframes at Dryandra.
- Finalise manuscript for publication.



## Decision support system for prioritising and implementing biosecurity on Western Australia's islands

SP 2013-001

C Lohr, K Zdunic, K Morris, L Gibson

### Context

The goal of this project is to prioritise island management actions such that we maximise the number of achievable conservation outcomes for island biodiversity in the face of threats from invasive species. Western Australia has over 3,700 islands, many of which are essential for the survival of threatened species, are popular sites for recreation, and contain culturally significant sites. Invasive species are the single biggest cause of loss of native species from islands. The increased use of islands by the public for recreation, and extraction industries, means an increased likelihood that invasive species will colonise pristine islands. This project will develop: 1) decision support software for day-to-day use in making accountable and cost-effective decisions on the management of islands to promote the persistence of native species; and 2) an island biosecurity model for prioritising biosecurity actions. The project will focus on the islands along the Pilbara coast.

### Aims

- Develop a single comprehensive database on Pilbara island characteristics, fauna and flora values, and threats.
- Develop an operational decision support software (DSS) for day-to-day use in making accountable and cost-effective decisions about where to spend limited funding on management of islands to promote the persistence of native species (Islands DSS).
- Develop an island biosecurity model for use in prioritising surveillance tasks for non-indigenous species on Pilbara islands (Biosecurity Bayesian Belief Network (BBN) software).

### Progress

- Validation of the Islands DSS continued after additional bugs were discovered.
- A manuscript discussing use of the Biosecurity BBN for identifying islands that are high priority weed management sites was accepted for publication in *Conservation Science and Practice*.
- A manuscript discussing the prediction of habitat types on remote Pilbara islands is in preparation.
- Software manuals and a comprehensive report of all research used in the development of the Islands DSS and Biosecurity BBN have been drafted.

### Management implications

- The Islands DSS will result in more cost-effective management of island conservation reserves.
- The Biosecurity BBN software will allow more cost-effective surveillance of islands for invasive species.
- A single comprehensive and easily accessible database on Pilbara island characteristics, biodiversity values and threats will facilitate island planning and management.
- A species demographic attributes and interactions database will facilitate development of population viability assessments and community ecology models for species management across Western Australia.
- Easier access to the cost and efficacy of past management actions will be beneficial when planning future management actions.

## Future directions

- The project will be complete once the report and publications are finalised.



## Conservation and management of the bilby in the Pilbara

SP 2012-035

M Dziminski, F Carpenter

## Context

The greater bilby (*Macrotis lagotis*) is listed as vulnerable under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999*. Increases in threats, including pressure from mining activities across the Pilbara, means that greater understanding of the distribution, abundance and ecology of the bilby is necessary to ensure appropriate conservation and management measures are implemented. This project aims to increase our understanding of the bilby in the Pilbara bioregion of Western Australia and allow for the development of a regional survey and monitoring program. The current focus is to determine the distribution of the bilby in the Pilbara and to establish appropriate survey and monitoring techniques, including genetic approaches.

## Aims

- Improve our understanding of the distribution and demographics of bilbies in the Pilbara.
- Provide information to environmental regulators, resource development companies and contractors that will allow appropriate management to ensure the long-term persistence of the greater bilby in the Pilbara.
- Design, establish and implement a long-term monitoring program for bilbies in the Pilbara.

## Progress

- The dataset of recent and historic records was finalised. An accurate distribution of bilbies in the Pilbara was generated, with areas of unknown status identified. A paper on the range of the bilby in the Pilbara was published in *Journal of the Royal Society of Western Australia*.
- Finalised development of abundance monitoring technique using non-invasive DNA collection from scats coupled with spatially explicit capture-recapture analyses. Wild populations in the Pilbara were relatively small, isolated, and particularly vulnerable to threats; two populations went extinct during this study. A paper on monitoring the abundance of wild and reintroduced bilby populations has been accepted for publication in *Journal of Wildlife Management*.
- A collaborative project with the Warralong Community, Roy Hill, and Greening Australia continued with monitoring of the Warralong bilby population and remote camera work and sign plots for predator, feral herbivore and bilby occupancy undertaken. Initial fire management has been implemented.
- Abundance monitoring of populations in the Pilbara continued.
- Ongoing advice on bilby occupancy survey, abundance monitoring and management has been delivered to mining and consultancy companies.
- Diet analysis of bilbies from 17 populations across Western Australia is underway.

## Management implications

- Recommendations regarding standardised survey and monitoring techniques for bilbies in the Pilbara bioregion will maximize comparability across sites to better inform conservation management.
- Improved understanding of the conservation status of bilbies in the Pilbara and elsewhere in Western Australia, including preferred habitat will inform future management of bilby populations and assist in the assessment of mining and development proposals.
- Geographically isolated and small population of bilbies in the Pilbara highlight the importance of threat managements such as unmanaged fire regimes.
- Surveys using remotely piloted aircraft (RPA) show future potential but require refinement.



- Knowledge of bilby diet preferences will assist in habitat management and assessment of managed sites in terms of food resource availability.

### Future directions

- Progress a distribution model of bilbies in the Pilbara, including ground truthing.
- Refine RPA technology as a survey tool.
- Initiate collaborative implementation of threat management with initial focus on fire management at selected populations with community and stakeholder engagement and support.
- Progress a population genetics analysis using existing bilby DNA library collected from population monitoring and opportunistically collected scats.
- Finalise analysis of diet results in conjunction with on-ground food availability plots.



### Genetic assessment for conservation of rare and threatened fauna

SP 2012-034

K Ottewell, M Byrne, S McArthur, R Sun, L Umbrello

### Context

Genetic analysis of threatened species can provide important information to support and guide conservation management. Genetic information can aid resolution of the taxonomic identity of species and sub-species to determine whether they have appropriate conservation listing. At a population level, analysis of the genetic diversity present, and its distribution across extant populations, provides information on the genetic 'health' of threatened species. Concurrent analysis of some of the proximal drivers of genetic change can identify appropriate management responses for declining populations to improve conservation outcomes. Further, emerging genomic technologies are enabling novel genetic monitoring approaches, expanding the available toolbox for threatened species monitoring.

### Aims

- Resolve taxonomic boundaries of Western Australian bandicoots (*Isoodon* sp.) to determine appropriate conservation rankings and management units.
- Assess diversity of island and mainland golden bandicoots and success of reintroductions.
- Assess genetic diversity and genetic structure of black-flanked rock wallaby (*Petrogale lateralis* ssp. *lateralis*) to inform ongoing management and success of translocations.
- Contribute to assessment of sub-species boundaries within northern quolls (*Dasyurus hallucatus*).
- Investigate genetic diversity of translocated brushtail possums (*Trichosurus vulpecula*) at Matuwa.
- Contribute to taxonomic assessment of brushtail possums, including resolution of Western Australian sub-species.
- Assess genetic diversity, genetic structure and monitor cave use of ghost bat (*Macroderma gigas*) populations in the Pilbara.
- Develop high-throughput genotyping array and molecular sexing markers for individual identification of ghost bats from faecal DNA.
- Assess species composition and individual relatedness of Hamelin Bay pilot whale (*Globicephala* sp.) stranding.
- Assess success of non-invasive DNA sampling from humpback dolphins (*Sousa sahalensis*) using drones.
- Assess genetic diversity across wild, translocated and historical populations of Gilbert's potoroo (*Potorous gilbertii*).
- Assess genetic diversity and genetic connectivity amongst Pilbara leaf-nosed bat (*Rhinonicteris aurantia* (Pilbara)) roosts and patterns of sex-biased dispersal.
- Assess use of faecal DNA sampling to estimate population size of mala (*Lagorchestes hirsutus* subsp. (Central Australia)) at Matuwa.

## Progress

- Mitochondrial and microsatellite analysis of Western Australian and eastern *Isoodon* sp. is complete, a manuscript has been published in *Australian Journal of Zoology* and another is to be submitted. Genomic analyses to further resolve closely-related taxa is underway.
- Genomic analysis of island, mainland and reintroduced populations of *I. auratus* is underway.
- Analysis of the Kalbarri National Park translocation of black-flanked wallaby is complete and a manuscript is in preparation.
- Genomic analysis of museum specimens and contemporary samples of northern quolls is underway.
- Analysis of the translocated brushtail possum population at Matuwa is complete and a manuscript has been published in *Pacific Conservation Biology*.
- Genetic monitoring of ghost bats at West Angelas, the Robe Valley and South Flank mining precincts has been completed and reports provided.
- Molecular sexing markers for use with microsatellite genotyping have been identified for ghost bats and a manuscript published in *Genes*. A reduced SNP array for high throughput analysis of scats has been designed and is now operational.
- DNA barcoding and microsatellite data from Hamelin Bay pilot whales is complete.
- DNA analysis of dolphin blow samples from drone sampling has been completed and a manuscript published in *Ecosphere*.
- Tissue samples from wild, translocated and historical populations of Gilbert's potoroo have been sourced and DNA extractions are underway.
- Genomic data have been generated for Pilbara leaf-nosed bat populations and preliminary data analyses are underway.

## Management implications

- Genetic assessment of wild and reintroduced populations of golden bandicoots will inform future translocations and genetic management of existing populations (e.g. Matuwa).
- Molecular identification of golden and northern brown bandicoots in the Kimberley will support discrimination of additional characters for field identification.
- The Kalbarri National Park translocation of rock wallabies demonstrated establishing founder populations from mixed Wheatbelt and Cape Range animals increased genetic diversity. Successful reproduction between extant Kalbarri animals and introduced animals was confirmed.
- Interbreeding of Barrow Island and Shark Bay boodies at Matuwa has been successful, resulting in high genetic diversity, with no impacts of introgression on survivorship and fecundity (outbreeding depression).
- Brushtail possums at Matuwa have relatively good genetic health currently, although they are at risk of decline and loss of genetic diversity due to small population size.
- Non-invasive genetic monitoring of ghost bats is providing insight into the species' ecology to inform potential impacts and responses to development. High-throughput SNP genotyping methods has enabled more rapid, cost-effective and reproducible screening of faecal DNA samples for monitoring.
- Genetic analysis of Gilbert's potoroo will inform a population management strategy to ensure genetic diversity is conserved in this endangered species.
- Genetic analyses of Pilbara leaf-nosed bat will assess genetic connectivity, cave use and sex-biased dispersal.

## Future directions

- Analysis of genomic data from island, mainland and reintroduced populations of *I. auratus* will be progressed.
- Genomic analyses will investigate genetic impacts of management interventions on rock wallaby populations, while analyses of historical and contemporary diversity will document recent evolutionary history.
- Genetic monitoring of Pilbara ghost bats will continue and a retrospective analysis of monitoring data will be used to develop optimal sampling methodology for mark recapture analyses.
- Genomic analysis of Gilbert's potoroo will be undertaken and information contributed to the population management strategy.
- Genomic analysis of Pilbara leaf-nosed bat will be completed.



## Genetic approaches for evaluating the contribution of the reserve system to fauna conservation

SP 2012-033

K Ottewell, M Byrne, S McArthur

### Context

Human-mediated landscape disturbance can affect the amount of genetic diversity present in populations of threatened species and their distribution across the landscape. One challenge facing conservation managers is understanding how management tools can be used to protect and facilitate genetic patterns and processes. For example, reserve design principles (comprehensiveness, adequacy, representativeness; single large or several small) can be just as well applied to conserve genetic diversity as species diversity. We aim to use genetic approaches to investigate patterns of contemporary and historical diversity in target species to understand how best to conserve the processes that generate these patterns.

### Aims

- Determine genetic diversity and gene flow amongst quenda (*Isodon obesulus* ssp. *fusciventer*) populations in fragmented and continuous habitat in the Perth region to assess the impacts of vegetation connectivity on genetic and demographic processes.
- Identify landscape elements that are associated with high genetic diversity and gene flow in quenda populations using GIS and connectivity modelling, and how well these features are captured in the reserve system.
- Assess the genetic diversity and genetic structure of small mammal species in the Pilbara, how this relates to climate and environmental features (soils, landforms, etc.), and how well it is captured in the current reserve system.

### Progress

- Analysis of genomic data is underway on three Pilbara mammal species *Pseudomys chapmani*, *P. hermannsburgensis* and *Ningauai timealeyi*, including model simulations to investigate the power of genomic data to resolve fine-scale genetic structuring.

### Management implications

- Genetic analyses of population structure of quenda across the Perth region demonstrated that landscape elements such as remnant vegetation and presence of low vegetation assist in maintaining connectivity among quenda populations. The identification of four genetic clusters that represent management units and are delimited by geomorphic features, such as the Swan River and wetland boundaries, provides information for management of the species across the Perth region.
- Use of more powerful markers should provide additional resolution of weak genetic structure in the three widespread Pilbara mammal species and identify landscape hotspots and barriers, demonstrating the effects of the boom-bust cycles of arid mammals, and a relatively high capacity for dispersal in the maintenance of spatial genetic patterns.

### Future directions

- Complete analysis of the genetic diversity and structure of small mammal species in the Pilbara through genomics.



## Barrow Island threatened and priority fauna species translocation program

SP 2012-025

L Gibson, A Burbidge, J Dunlop, C Sims, J Angus, M Blythman, S Garretson, K Rayner

### Context

Barrow Island Nature Reserve is one of Australia's most important conservation reserves, particularly for mammal and marine turtle conservation. It has also been the site of a producing oil field since 1964. In 2003, the Western Australian Government approved the development of the Gorgon gas field off the north west of Barrow Island, and associated LNG plant on Barrow Island, subject to several environmental offset conditions. One of these offsets was the threatened and priority fauna translocation program that provided for the translocation of selected Barrow Island fauna species to other secure island and mainland sites. This will assist in improving the conservation status of these species, and also allow the reconstruction of the fauna in some areas. It also provides an opportunity to examine the factors affecting translocation success, and improve these where necessary. Targeted species are the golden bandicoot, brushtail possum, spectacled hare-wallaby, boodie, water rat, black and white fairy-wren, and spinifex bird.

### Aims

- Translocate selected mammal and bird species from Barrow Island to other secure island and mainland sites.
- Reconstruct the fauna in areas where these species have become locally extinct.
- Develop and refine protocols for fauna translocation and monitoring.

### Progress

- In preparation for a proposed translocation of rakali (water rats) from Barrow Island to the Montebello islands, cameras were established at 36 locations along the coast, with 199 detections at 12 locations recorded. Four individuals were also captured at the offloading facility and LNG jetty areas, with DNA and scat samples collected for analysis. Several release locations in the Montebello islands were identified.
- Boodies translocated from Barrow Island to a fenced enclosure at Matuwa continued to be monitored, with fluctuations in population estimates corresponding to environmental conditions.
- Golden bandicoots also continued to be monitored outside the enclosure at Matuwa, with signs of persistence.
- Monitoring of golden bandicoots on Doole and Hermite islands, spectacled hare-wallabies on Hermite Island and boodies on Alpha Island was undertaken confirming all species continue to thrive on these islands.
- Introduced predator management continued at Matuwa and Cape Range National Park, with a more strategic approach implemented.
- Papers on Barrow Island fauna translocations have been submitted to *Pacific Conservation Biology* and *Wildlife Research*.

### Management implications

- Arid zone rangelands fauna reconstruction and conservation techniques developed by this project will have broad State and national application.
- The outcomes of the project are contributing to the management of DBCA and jointly managed rangeland properties and providing guidance for other fauna reconstruction projects such as the Dirk Hartog Island National Park Ecological Restoration Project.
- This project has contributed to an improvement in the conservation status of several threatened fauna taxa (e.g. boodie) and provided the basis for ongoing monitoring of fauna of the Montebello islands.

### Future directions

- Continue preparation for a proposed translocation of rakali to the Montebello islands.

- Continue to implement the Barrow Island fauna translocation strategy, including the ongoing monitoring of translocated populations according to the schedule.
- Continue monitoring the effectiveness of integrated fox and feral cat baiting at Cape Range and consider a fauna translocation contingent on the effective control of introduced predators.
- Review monitoring data of the fauna translocated to the Montebello islands to inform future monitoring.



## Rangelands restoration: reintroduction of native mammals to Matuwa (Lorna Glen)

SP 2012-024

C Lohr, L Gibson

### Context

Operation Rangelands Restoration commenced in 2000 with the acquisition of Lorna Glen (Matuwa) and Earraheedy (Kurrara Kurrara) ex-pastoral leases by the Western Australian Government. This 600,000 hectare area is now the site for an ecologically integrated project to restore ecosystem function and biodiversity in the rangelands. We are working in collaboration with the traditional owners, Tarlka Matuwa Piarku Aboriginal Corporation (TMPAC), who were granted Native Title (exclusive possession) over Matuwa and Kurrara Kurrara in 2014. Matuwa, and deserts to the north and east, once supported many mammal species. These areas have suffered the largest mammal declines in Western Australia. This project seeks to reintroduce 11 arid zone mammal species following the successful suppression of feral cats and foxes. Mammal reconstruction will also contribute to the restoration of rangeland ecosystems through re-establishment of ecosystem services such as digging, grazing/browsing of vegetation and seed dispersal.

The first mammal reintroductions commenced in August 2007 with the release of bilby (*Macrotis lagotis*) and brushtail possums (*Trichosurus vulpecula*). Between 2010-2012, mala (*Lagorchestes hirsutus*), Shark Bay mice (*Pseudomys fieldi*), boodies (*Bettongia lesueur*) and golden bandicoots (*Isodon auratus*) were translocated into an 1,100 hectare introduced predator-free fenced enclosure. The enclosure is intended to provide species with an opportunity to acclimatise to the desert environment, with the ultimate goal being to release animals outside the enclosure, and establish free-ranging self sustaining populations of these species.

### Aims

- Develop effective feral cat control techniques in a rangeland environment.
- Reintroduce 11 native mammal species to Matuwa by 2023, and contribute to an improved conservation status for these species.
- Re-establish ecosystem processes and improve the condition of a rangeland conservation reserve.
- Develop and refine protocols for fauna translocation and monitoring.
- Determine the role of digging and burrowing fauna in a rangeland ecosystem.

### Progress

- A manuscript discussing the need for an integrated pest management approach to feral cats was published in *Science of the Total Environment*.
- Manuscripts discussing interactions between wild dogs and feral cats on Matuwa were published in *Movement Ecology* and *Wildlife Research*.
- The persistence of bilbies and brushtail possums at Matuwa has been confirmed via camera-traps, and a manuscript is in preparation.
- Low numbers of golden bandicoot tracks continue to be detected in the Bullimore Sand Plain.
- Boodies, golden bandicoots and mala are persisting in the enclosure, with boodie numbers fluctuating dramatically in response to environmental conditions.

### Management implications

- Fauna reconstruction increases the probability of species persistence through the establishment of multiple populations, and it re-establishes ecosystem processes lost during localised extinctions.

- Flexibility in timing is a key consideration in the planning of reintroductions, which should also take into account the effects of environmental conditions (droughts) and annual cycles of reproduction/behaviour in potential predators/competitors on reintroduction success.
- Detailed monitoring to identify causes of mortality and the subsequent identification of predators and their removal in a timely fashion are critical to the success of reintroduction programs. Monitoring has demonstrated that additional cat control techniques to landscape scale baiting are required to successfully re-establish threatened vertebrate fauna in the rangelands.
- Sourcing founder animals from multiple locations has proven valuable in increasing genetic diversity in reintroduced species.
- Increased involvement of traditional owner rangers with fauna monitoring has assisted collaborative management arrangements.

### Future directions

- Ongoing monitoring of reintroduced species and introduced predators.
- Complete analysis of last 10 years of monitoring data.
- Complete publications on the ecology of boodies and golden bandicoots.
- Validate the accuracy of the 100km linear track transect by comparing data collected in 2020 to actual estimates of feral cat density.



### Feral cat control and numbat recovery in Dryandra Woodland and other sites

SP 2012-023

A Friend

### Context

Dryandra Woodland supports important populations of several threatened mammals, including the numbat, woylie and red-tailed phascogale, as well as significant populations of a number of threatened birds. Recent research has shown that feral cats are responsible for the majority of numbat and woylie deaths. This project investigates the feasibility and efficacy of using the *Eradicat* feral cat bait to reduce numbat and woylie mortality and promote their recovery at Dryandra.

### Aims

- Determine the uptake of rhodamine-labelled non-toxic *Eradicat* baits by chuditch, red-tailed phascogales and mardos in Dryandra.
- Determine the survival or mortality of groups of radio-collared chuditch, red-tailed phascogales and mardos during a baiting campaign using toxic *Eradicat* baits in Dryandra.
- Determine the survival or mortality of feral cats through a baiting campaign using toxic *Eradicat* baits in Dryandra.

### Progress

- A group of radio-collared numbats in Dryandra has been monitored under a regime of fox and cat control by baiting with both *Probait* and *Eradicat*. Forensic techniques have been applied to the remains and collars of dead numbats, including swabbing for predator DNA. During the year, six numbats were found dead. Causes of death included predation by carpet python (1), chuditch (3), raptor (1) and another indeterminate but probably raptor. There was no case of predation by fox or cat.
- A manuscript on red-tailed phascogales was submitted to *Wildlife Research*.

## Management implications

- *Eradicat* baiting is effective in controlling cats and can be used with minimal non-target impact in the Dryandra Woodland. This is significant for the implementation of integrated fox and feral cat control programs at Dryandra and elsewhere in the south-west of Western Australia.

## Future directions

- This project will be complete with publication of the manuscript on red-tailed phascogales.



## Conservation of south coast threatened birds

SP 2012-022

A Burbidge, A Clarke

### Context

Identifying the conservation requirements of threatened south coast birds, such as the critically endangered western ground parrot, endangered noisy scrub-bird, vulnerable western bristlebird and western subspecies of the western whipbird, and the endangered Australasian bittern, will aid *in situ* management of these taxa. Understanding responses to fire and hydrological changes, biological and behavioural characteristics (such as vulnerability to predation) and nesting site requirements are essential knowledge for the conservation of these Western Australian birds (some of them endemic to the south-west) and the development of management programs.

### Aims

- Develop an understanding of the biological and ecological factors that limit the distribution and numbers of south coast threatened birds, including interactions with predators, habitat requirements and response to fire.
- Increase the survival chances of south coast threatened birds and increase their total population size through creation of management prescriptions that will benefit all threatened south coast animals.
- Investigation of life history characteristics and ecological processes impacting on recruitment in the Australasian bittern.
- Survey and monitor Australasian bittern populations and habitat to assist tracking current trends.

### Progress

- A paper on field testing of recording units, in relation to scrub-bird and ground parrot calls, was accepted for publication in *Emu - Austral Ornithology*.
- An analysis of occurrence of western bristlebirds in relation to fire over several decades in Fitzgerald River National Park was submitted for publication.
- Monitoring of scrub-birds at Two Peoples Bay has failed to identify obvious reasons for recent declines, although potentially contributing factors (including fire and predators) were identified. A paper has been accepted for publication in *Pacific Conservation Biology*.
- An evaluation of feral cat control and impacts on western ground parrots was submitted for publication in *Wildlife Research*.
- Population monitoring of western ground parrots and development of risk assessments were undertaken ahead of a proposed translocation.
- A short note in *WA Bird Notes* was published showing that Australasian bitterns forage mainly in the day rather than mostly at night as previously believed.
- Extensive surveys for Australasian bitterns were conducted and ARUs deployed as part of a collaboration with Birdlife Australia. Progress was made in using automatic recogniser software to identify Australasian bittern calls from autonomous recorder units.

- Depth and rainfall at sites known to be important for the Australasian bittern continued to be monitored.
- Experience was gained in deploying traps to catch Australasian bitterns for fitting birds with satellite trackers, but no birds were captured due to unseasonably dry conditions.

### Management implications

- Knowledge of the biology and responses to threats of south coast threatened birds provides a basis for decision making and management actions for their recovery, especially with respect to introduced predators and fire, in important conservation reserves on the south coast.
- The collection of high quality depth and water quality data will be critical to the development of modelling designed to predict the hydrological futures for high priority bittern breeding wetlands. These research findings will help inform stakeholders and land managers where to target mitigation strategies.

### Future directions

- Complete publication on survey data for ground parrots, scrub-birds, bristlebirds, and bitterns.
- Complete publication on occupancy of ground parrots in relation to fire.
- Carry out a translocation of western ground parrots from the one remaining population to a safe site further west on the south coast.
- Conduct trial GPS tracking of Australasian bitterns, and continue to monitor key populations of Australasian bittern and their habitat so that trends can be tracked and communicated to stakeholders and inform management.



## Ecology and management of the northern quoll in the Pilbara

SP 2011-005

J Dunlop

### Context

The northern quoll (*Dasyurus hallucatus*) is listed as a threatened species under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999*. Funding from mining offset conditions is being used to gain a better understanding of quoll distribution, ecology, demographics and management requirements in the Pilbara. The two major components of the project are regional monitoring and ecological research. Regional survey and monitoring of Pilbara northern quoll populations over 10+ years will provide a regional context for understanding population dynamics. Researching northern quoll ecology will provide information related to impacts, such as loss of known or potential habitat critical to the survival of the species, loss of known or potential foraging/dispersal habitat, and introduction of barriers restricting dispersal opportunities and genetic flow.

### Aims

- Develop appropriate and standardised survey and monitoring methods for northern quoll.
- Define areas of critical habitat and better understand how disturbance affects habitat quality.
- Improve understanding of population dynamics.
- Better understand the key threats and interactions between these threats.
- Determine whether the northern quoll will colonise restored / rehabilitated areas or artificial habitat.

### Progress

- Occupancy modelling using a significant number of northern quoll detections collected via camera and cage trapping is being progressed.



- Downward-facing cameras were used for population estimation via individual identification, and has allowed analysis of detection probabilities for northern quolls and several other species.
- Examining the relationship between presence of quolls and both predators and habitat variables continued.
- Efficacy of Felixer grooming traps as another tool for managing feral cat numbers in the presence of quolls is currently being trialled.
- An albino northern quoll was captured and reported on, the second record for the species and one of 10 albino quolls ever recorded.

### Management implications

- Northern quoll distribution models indicate key populations (i.e. high density areas) to be protected from future threatening processes and allow for more informed decisions.
- Modelling the changes in mortality of different cohorts of northern quolls has enabled best-practice baiting regimes to be implemented for feral cats in the Pilbara.
- Investigations into habitat used for denning by female northern quolls has provided guidance for the creation of suitable artificial habitat.
- Felixer feral cat grooming traps have been demonstrated to be safe for use in the presence of northern quolls.
- Camera traps show promise as an alternative monitoring tool to cage trapping.

### Future directions

- Continue an assessment of camera traps vs trapping as a monitoring technique for northern quolls, and update guidelines for population assessment.
- Population genetics for Pilbara northern quolls will be assessed to reveal information about the important northern quoll conservation units, genetic diversity within the region and effective home range size.
- Continue investigation into the interactions between northern quolls and introduced species.
- Northern quoll denning requirements will be further examined in relation to other habitat features in the landscape, other predator/prey interactions, and optimal size and structure of rockpiles.
- Testing of Felixer feral cat control units will continue with 1080 toxin.



### Conservation of the graceful sun-moth

SP 2010-006

M Williams

### Context

This project focuses on a high-profile invertebrate that was a listed threatened species under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, and as Scheduled Fauna under the Western Australian *Wildlife Conservation Act 1950* until 2012. The graceful sun-moth (*Synemon gratiosa*) is a day-flying moth restricted to the Swan Coastal Plain, and is threatened by urban and other development. This project will obtain information to resolve potential conflicts between conservation of the species and the impacts of land clearing and by involving community organisations and environmental consultants, cooperative partnerships with the community are extended.

### Aims

- Undertake research to determine the distribution and habitat requirements of the graceful sun-moth.
- Develop survey techniques to accurately determine the presence of the species, and to assess its abundance in bushland areas.
- Document or identify which factors determine the realised niche of the species, using habitat suitability modelling.
- Review the conservation and taxonomic status of the graceful sun-moth using molecular genetic methods.
- Identify land clearance management strategies to enable effective conservation.

## Progress

- A paper detailing unrecorded information on the life history of the graceful sun-moth has been submitted for publication, providing information on fecundity and survival rates that is important for understanding population dynamics.
- A study of the abundance of the graceful sun-moth in Perth's urban bushlands and its response to fire has been completed and a paper drafted.

## Management implications

- Knowledge on the distribution and habitat requirements has provided information to inform management of urban bushland.

## Future directions

- This project will be complete when publications are finalised.



## Impact of cane toads on biodiversity in the Kimberley

SP 2006-004

D Pearson

## Context

The invasion of cane toads is impacting on the biodiversity of the Kimberley and no technique has been developed to prevent their spread across the landscape. Earlier research in this project has identified that predators, such as northern quolls (*Dasyurus hallucatus*) and goannas, are especially vulnerable to poisoning by toads and we have identified that it is possible to train some native predators to avoid eating cane toads. A taste aversion bait to prevent quolls eating toads has been developed and is being trialled during this project. Monitoring of northern quoll and reptile populations on Adolphus Island is required to understand how these species are likely to respond to the arrival of toads on islands.

## Aims

- Test of taste aversion baits and the use of 'teacher toads' (metamorphs too small to be lethal) to induce an effective conditioned taste aversion (CTA) response from native species threatened by toads.
- Develop operational techniques to roll out taste aversion training across Kimberley landscapes.
- Research techniques for taxa not currently believed to be able to benefit from taste aversion training such as elapid snakes.
- Monitor populations of susceptible species behind the toad front, including those where taste aversion training took place and control sites.
- Investigate where and how toads survive in seasonally dry habitats to better understand their colonisation of islands and their potential to spread into the Pilbara region.

## Progress

- Camera and trapping data for a taste aversion trial with northern quolls on Theda Station was analysed and prepared for publication.
- Three-monthly surveys of Adolphus Island were undertaken to assess faunal responses to toads that have rafted onto the island and established a population. Foot searches and trail cameras indicate continued persistence of quolls and a number of toad-sensitive goanna species.
- Camera arrays were established at three additional sites in the north Kimberley to assess the success of a 2018 taste aversion bait drop at Faraway Bay.
- Trials of aerial CTA bait drops were conducted in Mitchell River NP and Prince Regent River NP.

- The 'waterless barrier' concept to prevent the spread of toads out of the Kimberley was examined by literature review, some field inspections and discussions with local land-holders and researchers familiar with the hydrology and wetland vegetation in the area. A discussion paper was prepared to canvas the issues involved in its implementation and the likelihood of success.

### Management implications

- CTA provides a technique to reduce the impact of cane toads on quolls.
- The use of 'teacher toads' improves the survival of floodplain goannas in small scale trials and work is continuing to develop techniques to scale up the area that can be treated.
- The continued survival of quolls and other toad-susceptible species on Adolphus Island indicates that toad invasion of seasonally dry islands may not cause the extinction of their populations. Toads survive on Adolphus Island by selecting particular microhabitats and this confounds contemporary belief that survival is only possible for a few days without surface water.

### Future directions

- Complete CTA bait development for quolls and prepare publication.
- Complete experimental CTA baiting in areas being invaded by cane toads.
- Write up the survival strategies of cane toads during the late dry season on Adolphus Island.



### Development of effective broad-scale aerial baiting strategies for the control of feral cats

SP 2003-005

D Algar, N Hamilton, M Onus

### Context

The effective control of feral cats is one of the most important native fauna conservation issues in Australia. Development of an effective broad-scale baiting technique, and the incorporation of a suitable toxin for feral cats, is cited as a high priority in the national *Threat abatement plan for predation of feral cats*, as it is most likely to yield a practical, cost-effective method to control feral cat numbers in strategic areas and promote the recovery of threatened fauna.

### Aims

- Design and develop a bait medium that is readily consumed by feral cats.
- Examine bait uptake in relation to the time of year, to enable baiting programs to be conducted when bait uptake is at its peak and therefore maximise efficiency.
- Examine baiting intensity in relation to baiting efficiency to optimise control.
- Examine baiting frequency required to provide long-term and sustained effective control.
- Assess the potential impact of baiting programs on non-target species and populations and devise methods to reduce the potential risk where possible.
- Provide a technique for the reliable estimation of cat abundance.

### Progress

- Refinement of bait composition to improve bait attractiveness/palatability has continued with pen trials underway to assess incorporating two additional amino acids into the mix.
- Oil derived from a plant that elicits a chewing response in cats is also being examined to see if it enhances bait palatability and bait consumption.
- Trials of the *Hisstory*<sup>®</sup> feral cat bait for use in northern Australia continue with pen trials showing that the formulation is an efficacious toxicant for feral cats.
- Field efficacy trials demonstrated that *Hisstory*<sup>®</sup> is unlikely to present a significant hazard to native species, but techniques to minimise the risk to wild dogs/dingo hybrids have proved less successful.

- A manuscript about using activity and movement patterns to improve the rate of bait encounter during large-scale aerial baiting for feral cats has been submitted to *Australasian Journal of Environmental Management*.
- Refinement of the trapping technique to minimise risk to non-targets yet maintain effectiveness in feral cat capture is ongoing.
- Work continues to improve and refine several cat lures.

### Management implications

- Development of effective baiting methods across climatic regions will ultimately provide efficient feral cat control at strategic locations across mainland Western Australia and lead to significant conservation benefits.
- Successful eradication of feral cats from a number of islands off the Western Australian mainland has occurred over the past ten years (Hermite, Faure, Rottnest and recently Dirk Hartog Island), allowing the persistence of the native fauna on these islands and enabling effective reintroductions of mammals where appropriate, and restoration of habitat and ecosystem processes.

### Future directions

- Continue refinement of bait medium to improve bait consumption by feral cats.
- Analyse baiting effectiveness and refine the method of operation (targeted/strategic) where necessary to optimise baiting efficacy.
- Progress the development of feral cat baits with a minimised risk to canids through emesis to avoid intoxication.
- Undertake field efficacy trials for the *Hisstory*<sup>®</sup> feral cat bait.
- Further investigate bait consumption by non-target species and devise methods to minimise risk.
- Continue to refine and optimise cat lure options.



### Gilbert's potoroo recovery plan

SP 1996-008

A Friend

### Context

Gilbert's potoroo (*Potorous gilbertii*) is the world's rarest marsupial. Since its rediscovery in Two Peoples Bay in 1994, a range of actions have been undertaken to improve the probability of persistence of the species.

### Aims

- Implement the *Gilbert's Potoroo Recovery Plan*.
- Increase the numbers of individual Gilbert's potoroos known to be alive in the wild and increase the number of locations in which they occur.

### Progress

- Within the Waychinicup enclosure, the number of potoroos known to be alive remained stable at 25-30 individuals.
- Radio-tracking of seven potoroos at Waychinicup was undertaken to identify habitat use to inform selection of translocation sites.
- At Two Peoples Bay, one male and one female potoroo were fitted with GPS units with findings indicating that, just four years after the fire, the burnt habitat will support potoroos and that translocation of individuals to restock burnt areas should now proceed.

- Camera monitoring was established across the Mount Gardner headland immediately after the extensive fire in 2015. In July 2019, the first image of a potoroo at a burnt site was captured, over 1.3 km from unburnt habitat, well beyond the expected movement range of a potoroo.

### **Management implications**

- The establishment of two insurance populations and the earlier development of captive management protocols enabled effective management of potoroos from the Two Peoples Bay Nature Reserve population that was impacted by fire.
- Gilbert's potoroos can utilise suitable habitat much sooner after fire than was previously thought.
- Due to the small size of the Two Peoples Bay population, close management of all colonies to maximise numbers and genetic diversity will be required in planning translocations of potoroos.

### **Future directions**

- This project will be closed.



## Plant Science and Herbarium

**Program Leader: Colin Yates** Applied flora conservation research seeks to understand the factors and processes that are critical for the conservation of Western Australia's native plant diversity. Major objectives include ensuring the persistence of rare and threatened species, understanding key threats such as *Phytophthora* dieback and weeds, and improving the understanding of genetic and ecological factors that are vital for the long-term viability of plant species. Strong collaborative linkages exist with universities, cooperative research centres, CSIRO, other research providers such as the National Environmental Science Program and the corporate sector.

The program also includes the Western Australian Herbarium that houses the state collection of scientific specimens of plants, algae and fungi. Information in the collection underpins the conservation of the Western Australian flora. The Herbarium is responsible for: documenting and understanding the diversity of Western Australia's plants, algae and fungi; maintaining a research and archive collection of specimens of all species in these groups from throughout their range in Western Australia; helping the community, industry and researchers understand and identify plants, algae and fungi; contributing to, supporting and servicing the research, conservation and decision-making activities of government; contributing to taxonomic research by Australia's and the world's scientific community; providing authoritative information to government, industry and the community via the *FloraBase* website and the Herbarium's information management systems.



### Molecular characterisation of stinking passionflower (*Passiflora foetida*)

SP 2018-041

T Hopley, M Byrne, S van Leeuwen

#### Context

Stinking passionflower (*Passiflora foetida*), a perennial vine native to South and Central America, is a highly invasive weed in the Pilbara and Kimberley regions of Western Australia, and in other parts of the world. In the Pilbara, the weed is rapidly expanding its abundance in areas with slightly higher moisture availability than the surrounding landscape, including coastal reserves and riparian habitats. Options for effective management of the weed in these areas are limited and biological control is being investigated as a potential management strategy in collaboration with CSIRO. Limited knowledge of the biology and life history of stinking passionflower is a significant impediment for implementing effective weed management strategies, including biological control. Ecological and genetic characterisation is required to understand the invasion ecology of the species and to guide the search for suitable biological control agents from the native range.

## Aims

- Use molecular analysis of Australian collections, in the context of samples from the native range and other regions and countries where *P. foetida* is introduced, to identify and characterise the genetic entity(ies) present in Australia.
- Elucidate whether there are multiple origins for the Pilbara invasions.
- Confirm the level of relatedness of the invasive *P. foetida* to *Passiflora* species native to Australia and to commercial varieties.
- Characterise Pilbara populations relative to less invasive populations to identify any signal of adaptation.

## Progress

- Whole chloroplast sequencing analysis has been finalised and confirms the initial preliminary phylogenetic analyses that shows a main group which represents the Western Australia, Northern Territory and some of the Queensland locations clustering with samples from Ecuador, and two smaller groups that represent locations in Queensland and New South Wales, one which clusters with samples from Brazil and the other which clusters with samples from the Caribbean.
- A draft manuscript on the phylogeny is in preparation to identify the phylogenetic relationships of native, commercial and invasive *Passiflora* in Australia in the context of diversity in the native range of *P. foetida* in South America.
- Collection of 870 samples have been made from 37 populations from Queensland, 35 populations from Northern Territory and 14 populations from Western Australia to represent the introduced range in Australia.
- DNA extraction and sequencing at Diversity Arrays Technology of 1,100 samples has now been completed.

## Management implications

- Information on the potential taxonomic entities and origin of *P. foetida* in the Pilbara will inform the identification of, and guide the search for, putative control agents from the natural range.
- Information on local adaptation within invasive populations provides a basis to understand the dynamics of invasion and determine the effectiveness of potential control agents.

## Future directions

- Complete manuscript documenting results of phylogenomic analysis.
- Complete population genetic analysis for collections from the invaded range in Australia for investigation of population structure and genetic diversity, and prepare manuscript.
- Investigate the ability to recover adaptive loci, considering the low diversity that has been found in populations in Australia.



## Is restoration working? An ecological genetic assessment

SP 2016-015

M Byrne, M Millar, S Krauss, J Anthony

## Context

The recognition of poorly defined success criteria and a lack of long term monitoring have highlighted the need for the development of post implementation empirical evaluations of the quality of restoration activities. This recognition has led to the hypothesis that the most ecologically and genetically viable restored populations will be those where reproductive outputs, plant pollinator interactions, levels of genetic diversity, mating systems and patterns of pollen dispersal most closely mimic those found in natural or undisturbed remnant vegetation. These populations are more likely to persist in the long term and contribute to effective ecosystem function through integration into the broader landscape. This project aims to assess the success of restoration in terms of ecological and genetic viability for plant species in the Fitzgerald River-Stirling Range region of Western Australia, where significant investment is being made in restoring connectivity at a landscape scale.

## Aims

- Evaluate levels of genetic diversity for each of six target species, at each of the restoration sites at which they occur and in equivalent remnant reference sites.
- Evaluate mating system parameters for each of six target species, at each of the restoration sites at which they occur and in equivalent remnant reference sites.
- Evaluate patterns of pollen mediated gene dispersal in two proteaceous species.

## Progress

- Restoration populations of *Acacia cyclops* have similar levels of genetic diversity and mating systems are not genetically differentiated from remnant populations. A paper on genetic diversity and mating system among restoration and remnant populations has been published in *Restoration Ecology*.
- Restoration populations of *Melaleuca acuminata* have similar levels of genetic diversity and mating systems and are not genetically differentiated from remnant populations. A paper on genetic diversity, mating system, and reproductive output of restored populations compared to natural remnant populations has been published in *Ecological Restoration*.
- Genetic diversity and mating systems are similar in restoration and remnant populations of *Banksia media*. Patterns of pollen dispersal vary across restoration populations, and proximity to remnant vegetation enhanced pollen immigration into restoration populations. Seed weights varied among sites and were greater for remnant populations. A paper on pollen dispersal, pollen immigration, mating and genetic diversity in restoration populations has been published in *Biological Journal of the Linnean Society*.
- Genetic diversity and the mating system were largely equivalent among restoration and remnant populations of *Hakea nitida*, although divergence was surprisingly high. Patterns of pollen dispersal were random and pollen immigration was low in the restoration sites. A paper on pollen dispersal, mating system and genetic diversity has been submitted to *Restoration Ecology*.
- Analysis of *Hakea laurina* has shown that genetic diversity is maintained in restoration populations. A lower outcrossing rate was observed at one restoration site, with greater inbreeding in restoration populations. Invertebrate floral visitor abundance varied at sites but species richness was similar. A draft manuscript is in preparation.

## Management implications

- Comparable genetic diversity in restored and remnant populations of all species indicate that restoration practices have been effective in establishing initial genetic viability in restoration populations.
- Restoration populations appear to have been largely established with local provenance material with the exception of *H. nitida*.
- General equivalency in mating systems among restoration and remnant populations suggest the presence of biotic pollinators in restoration sites of varying ages.
- The enhancement of pollen immigration with proximity of restoration populations to remnants should be considered in targeting future restoration sites.

## Future directions

- This project will be complete when papers on *H. nitida* and *H. laurina* are finalised.



### Interactive key and taxonomic studies of Myrtaceae tribe Chamelaucieae

SP 2013-052

B Rye

## Context

Taxonomic revision is required in various plant groups to facilitate appropriate determination of their conservation status. The main group of plants under study, Myrtaceae tribe Chamelaucieae, comprises over 800 species of



shrubs, including over 100 unnamed species and subspecies. The lack of an adequate taxonomy continues to impede their conservation, study (in fields other than taxonomy) and commercial utilisation.

### Aims

- Publish a series of taxonomic papers describing many new species, most of which have conservation priority, and in some cases also describe new genera or sections.
- Maintain a draft *Flora of Australia* treatment of tribe Chamelaucieae of the Myrtaceae.
- Produce and continually update an interactive key to members of this tribe.

### Progress

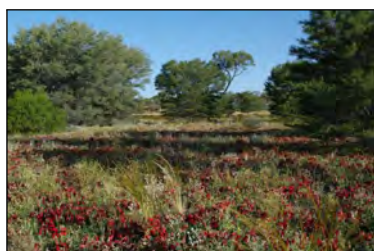
- Short communications on *Calytrix*, *Babingtonia* and *Thryptomene* have been published in *Nuytsia* and those on *Darwinia* and *Verticordia* (Myrtaceae) are in press.
- A paper on a new subtribal classification of Myrtaceae tribe Chamelaucieae has been published in *Australian Systematic Botany*.
- Papers on *Hypocalymma* and *Tetrapora* and new genera are in preparation.

### Management implications

- An improved understanding of the numbers and status of taxa will facilitate their management and conservation. For the large tribe Chamelaucieae, in which generic boundaries are still far from clear, an interactive key provides the best practical means of identification of all its members.

### Future directions

- Start investigation of generic boundaries in subtribe Chamelauciinae based on molecular and morphological evidence, making new combinations and describing new genera where required.
- Submit papers on new genera of Myrtaceae subtribe Chamelaucieae.
- Continue preparation of papers on *Hypocalymma* and *Tetrapora*.



### Strategic taxonomic studies in families including Amaranthaceae and Fabaceae (*Ptilotus*, *Gomphrena*, *Swainsona*) and other plant groups

SP 2012-006

R Davis

### Context

*Ptilotus*, *Gomphrena* and *Swainsona* are important genera, particularly in arid and semi-arid areas of Western Australia, such as the Pilbara and Midwest Regions, where they are often dominant components of the vegetation. This project undertakes basic taxonomic studies in these three genera, including the description of new species and taxonomic assessments of existing taxa, and preparation of a *Flora of Australia* treatment for the family Amaranthaceae. Development of interactive keys to all Western Australian species in the three genera are being undertaken, as these keys will allow easier and more accurate identifications of all species.

### Aims

- Publish new taxa and review infraspecific taxa in the genus *Ptilotus*.
- Create interactive keys to all Western Australian species of *Ptilotus*, *Gomphrena* and *Swainsona*.
- Publish new taxa in other genera.

### Progress

- Published a description of *Grevillea hystrix* (Protaceae) a poorly known species from the Coolgardie bioregion in *Nuytsia*.

- Published a description of *Stachystemon exilis* (Euporbiaceae), a potentially threatened species from the Swan Coastal Plain in *Nuytsia*.
- Published a description of *Teucrium diabolicum* (Lamiaceae) a new species from the Coolgardie bioregion in *Nuytsia*.
- Published a clarification of the *Ptilotus royceanus* species complex in *Austrobaileya*.
- Published a key to *Gomphrena* of Western Australia, *Keybase*.

### Management implications

- Clarifying the taxonomy and identification of *Ptilotus*, *Gomphrena* and *Swainsona* is important as these genera include indicator species and are significant for rangeland and arid land management and assessment. Many species are annuals, and *Swainsona* is a nitrogen-fixing legume. Some species of *Ptilotus* have been shown to have high phosphate uptake capabilities and are potentially useful in land restoration and rehabilitation programs. Several species within each genus are listed as threatened flora or are on the priority flora list. Having a sound taxonomic understanding of the species within these genera will enable the department to provide informed advice on the conservation status of the species and the communities they inhabit and how best they can be managed.

### Future directions

- Preparation of further papers describing new taxa in *Ptilotus*, *Gomphrena* and other genera.
- Further field studies to assist in the resolution of problematic groups within *Ptilotus*.
- Progress interactive keys to *Ptilotus*, *Gomphrena* and *Swainsona*.
- Finalise paper dealing with the synonymy of *Adenanthos pungens*.



## The Western Australian Plant Census and Australian Plant Census

CF 2011-111

C Parker, J Percy-Bower, R Rees, E Wood-Ward, T Macfarlane, S James

### Context

The Western Australian Plant Census (a component of WACensus) is the authoritative database of all names of plants in Western Australia, including synonyms created by taxonomic change. It is continually updated to reflect changes in our knowledge of the flora. The census constitutes the fundamental master list for many departmental processes and data sets, including the threatened and priority flora databases maintained by the Species and Communities Program, the Herbarium's specimen database, *Max*, *FloraBase* and *NatureMap*.

The Australian Plant Census (APC) is a project of the Council of Heads of Australasian Herbaria, designed to provide a consensus view of all Australian plant taxa. The APC delivers authoritative information on what species occur in Australia as a whole, to obtain accurate national statistics, and to resolve differences in opinion and knowledge for taxa that cross State boundaries. In addition to working systematically through the vascular plant families, the APC process provides for updates as taxonomic changes or new findings are formally published. The consensus also extends from family and genus level to an overall classification of the plants that occur in Australia. As the APC project continues, the Western Australian Plant Census is updated to reflect the consensus view. The APC provides the key name list for the Atlas of Living Australia and the Australasian Virtual Herbarium.

### Aims

- Maintain an accurate and timely listing of all plants, algae, and fungi in Western Australia, including both current names and synonyms, and integrate this with the national taxonomic consensus.

### Progress

- Seven hundred and thirty two plant names (704 formally published and 28 informal names) were added to the WACensus.

- A total of 1,812 other edits were made to the WACensus.
- WACensus updates were regularly distributed to 264 registered Max users.
- Provided critical review of several years backlog of APC name updates resulting from ongoing taxonomic activity in Australia and internationally.
- Contributed to discussions on taxonomy and nomenclature to assist in reaching national consensus for the National Species List (NSL), also known as the Australian Plant Census.
- Contributed to discussions and testing of a new online approach to the current inefficient document based process of handling APC name updates.
- The State's contribution to maintenance of this national cooperative database continued with the addition of 114 new vascular plant names to the NSL database and creation of 543 new instances (data on synonymy and publications).

### Management implications

- WACensus provides users with a single, authoritative official list of plants for Western Australia, with their currently accepted classification, scientific name, correct spelling and authority. Delivery of this information is through the *FloraBase* website, Max (the department software for information based on taxonomic names) and other linked databases or websites.
- Users of plant names are able to access WACensus information to ensure that current information on names, taxonomic acceptance and occurrence in Western Australia is available for conservation status lists, publications, signage and legal requirements. Outdated names can be traced to their current status or updated name through WACensus.
- WACensus feeds Western Australian information to national biodiversity systems such as the Atlas of Living Australia, Australasian Virtual Herbarium, the Australian Plant Census (National Species List), and the e-flora of Australia. The national list contributes to international names databases such as the Global Biodiversity Information Facility and Encyclopedia of Life.

### Future directions

- Continue to provide a comprehensive and up to date census across all plant, algae, and fungal groups.



### The Western Australian Herbarium specimen database

CF 2011-110

J Percy-Bower, S James, S Sinha, R Gillen, S Williamson, E Wood-Ward, S Coffey

### Context

The Western Australian Herbarium specimen database (WAHerb) allows staff at the Herbarium to manage and maintain the Herbarium's collections, and provides core data on the distribution, ecology and morphology of all taxa for the department and the community, through the *FloraBase* and *NatureMap* websites. Data from the specimen database is provided to researchers, consultants and community members on request, and to the Australasian Virtual Herbarium (AVH), Atlas of Living Australia (ALA) and the Global Biodiversity Information Facility (GBIF) on a regular basis.

### Aims

- Capture, maintain and validate spatial, phenological, population and habitat data for the Herbarium botanical collections, enabling curation of the collection and providing core data for *FloraBase* and departmental decision support systems and research.

## Progress

- The Western Australian Herbarium added 9,938 specimens to collections, including 1,186 priority flora and 109 threatened flora.
- Regularly provided customised specimen data requests (species lists and label data) to departmental officers, researchers and the public.
- More than 51,000 specimen records were edited as part of activities aimed at ensuring the collection is scientifically valid, up-to-date and aligned with the department's conservation codes.
- Significant collections added to the Western Australian Herbarium included industry surveys, departmental regional surveys, Herbarium Research Associates and exchange specimens from Australasian herbaria: Ravensthorpe Range Survey, AusPlots Rangelands Survey, Kimberley Islands Biodiversity Survey and Yilgarn Calcrete Survey, as well as collections from GJ and BJ Keighery, CJ French, SD Hopper, G Byrne, JE Wajon, G Brockman, the National Herbarium of New South Wales (NSW) and the Australian National Herbarium.

## Management implications

- WAHerb represents the most comprehensive collections database for Western Australian plants available and provides a source of information that managers can use for updates on biodiversity or conservation status, plant identification, clarification of plants in an area, and identification of knowledge gaps. This ensures that all research and management activities use up to date and valid plant species names.

## Future directions

- Continue adding to, timely editing and validation of specimen records to maintain currency and connectivity between the Herbarium collection, the Western Australian Plant Census (WACensus) and external databases, including the Australasian Virtual Herbarium and Atlas of Living Australia.



## Herbarium collections management

CF 2011-105

S James, C Parker, J Huisman, J Percy-Bower, R Rees, S Coffey, E Wood-Ward, M Hislop, R Davis, O Nazarova, S Sinha, S Williamson

## Context

The Western Australian Herbarium houses the State botanical collections, the core resource for knowledge of the State's plants, algae, and fungi. The collection is growing constantly and consistently through the addition of accessions of new taxa and distribution records from internal and external sources. The collection is maintained to a high standard utilising international natural history collections and archival best practice, and provides the department and the community with the fundamental resource that provides knowledge of the diversity, temporal and spatial distribution, and abundance of the flora throughout Western Australia.

## Aims

- Document and audit the diversity of Western Australia's plants, algae, and fungi.
- Maintain, in perpetuity, a comprehensive and representative research collection of specimens of all taxa in groups occurring in, and adjacent to, Western Australia.
- Contribute to, support and service the research, conservation and decision-making activities of the department.
- Contribute to, support and service taxonomic and other research by the national and international scientific community.

## Progress

- The Western Australian Herbarium added 9,938 specimens to collections, increasing the size of the collection to 811,429 catalogued items, representing more than 18,500 taxa.

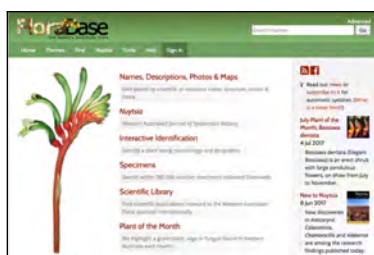
- More than 51,000 specimen data records were updated during the year, and through the Australasian Virtual Herbarium and Atlas of Living Australia, almost 25 million herbarium data records were downloaded in 20,200 download events.
- The Herbarium shared specimens with 12 national and 14 international institutions, and shipped almost 9,700 specimens in 146 transactions for scientific research. A total of 1,620 exchange specimens were sent to collaborating institutions, and 19 requests for more than 780 tissue samples from herbarium specimens were processed for molecular and other scientific destructive analyses.
- Major changes within the collections included the curation and rearrangement of the Pteridophyte (fern) and Ericaceae collections to reflect current taxonomic understanding. All Herbarium policies and procedures were updated and made available online, and a collaboration with the Department of Primary Industries and Regional Development and Quarantine WA resulted in improved importation procedures for herbarium specimens into Western Australia from other States.
- Tasks managed by collections staff with the assistance of volunteers included the mounting and labelling of 7,057 specimens and the incorporation (filing) of 31,148 specimens.
- Volunteer participation continues to be a significant and invaluable resource, totalling 7,719 hours, equivalent to approximately 4.5 full time employees. The Herbarium was assisted by about 60 regular volunteers and 35 Research Associates.
- The Reference Herbarium public facility was used by about 1,700 users during the year for plant identifications and other scientific purposes.
- The Research Collection was accessed by 740 visitors for the study and identification of taxa.
- More than 283 high resolution images of Herbarium specimens were captured and shared with departmental staff and industry consultants and a further 516 high resolution images of type specimens were captured and shared with the online Global Plants Initiative.
- The Herbarium Identification Program provided identifications to a range of clients including departmental staff, other government agencies, environmental consultancies, regional herbaria and the public. About 1,500 specimen identifications and 150 image-based identifications were undertaken for external clients.
- Educational role continued with staff providing eight tours and three induction sessions (270 participants) of the Herbarium for departmental staff, tertiary institutions, environmental consultancies, community groups and the media.

### Management implications

- Maintenance and curation of the Western Australian Herbarium botanical collections provides an authoritative inventory of the plant biodiversity of Western Australia underpinning flora conservation and national and international research programs.
- The collections are drawn upon constantly by department staff, consultants and others for validating specimen records from biological surveys and for assessing the conservation status of native taxa.
- The curated collections data is a much utilised digital resource for systematic and taxonomic research, collections management, environmental assessment, ecological and other scientific research, restoration and remediation projects, biosecurity management and planning, educational uses, and citizen science.

### Future directions

- Develop curation workflows and volunteer programs that enable the imaging of physical collections for online delivery and sharing.
- Significant reduction in current unprocessed and uncatalogued specimen items.
- Develop curated tissue collection with associated vouchers and maintenance plan for future molecular studies.
- Scope gap analysis program for collections.



## Biodiversity informatics at the Western Australian Herbarium

CF 2011-104

B Richardson

### Context

*FloraBase*, the web information system for the Western Australian flora, is the department's main means of communicating botanical taxonomic information. *FloraBase* draws from three corporate datasets maintained by the Herbarium, dealing with names (WACensus), specimens (WAHerb) and images (Imagebank). Managing the currency, authority, data quality and linkages between these datasets is an important task, both for the maintenance of *FloraBase* and for Western Australia's contributions to national and global plant information resources such as the Atlas of Living Australia (ALA) and the Global Biodiversity Information Facility (GBIF). WAHerb is the Herbarium's specimen database and is the sole source of specimen data used by *FloraBase*. Imagebank is the Herbarium's image collection.

### Aims

- Deliver authoritative taxon, specimen and image information on all Western Australian vascular plants, algae, fungi, lichens, mosses and slime moulds to a wide audience, using efficient, effective and rigorous web-based technologies.
- Deliver the department's biodiversity data to the internet using standards-compliant web services and data structures.

### Progress

- Determined the requirements for migration of WAHerb to new infrastructure.
- Reimplemented the *FloraBase* 3 database model using relational tables following a preliminary trial of a graph model.
- The user security layer was implemented, which will need further work to support departmental SSO if that gains OIDC capability.
- Implemented design functions including, Redis-based session management, draft Elasticsearch-based search feature for Advanced Search and Specimen Search, and draft support for editing taxon descriptions and making these searchable.
- Developed a draft data structure for WAHerb and WACensus data that informs the data migration process and the software evaluation process.
- Maintained the *FloraBase* application and content including upgraded infrastructure, regular *Nuytsia* sub-site updates to support ongoing journal releases and bug fixes; Imagebank; WAHerb including the addition of new fields and development of a migration path for the replacement collections management system; and the Publishing System including support for the changes made to fields, and the development of a migration path for WAHerb data.
- Evaluated options for a revised mapping infrastructure.
- Built a draft migration path for collectors and identifiers of specimens.

### Management implications

- *FloraBase* allows the community and department staff to retrieve the most recent information on the name, features, status and distribution of the 14,014 currently recognised native and naturalised Western Australian vascular plant taxa and 2,934 alga, fungus, lichen, moss and slime mould taxa. Species conservation and land management efforts across the State are made more effective by access to this authoritative information.
- WAHerb is the authoritative source of data for any application relying on Western Australian plant specimen data, and as such it is crucial to many applications, including *FloraBase*, Australasian Virtual Herbarium, the ALA and GBIF.

- Imagebank is the authoritative source of data for Western Australian vascular plant images, with full support for images of other taxon groups such as mammals, insects and fungi. It is also the source of data for other applications such as *FloraBase* and ALA.
- Involvement in national and international informatics collaborations enables Western Australia to participate fully in new developments in these areas, ensures that Western Australian data is made available to the broadest possible audience, and ensures that data from other sources can be integrated with local data for the more effective delivery of research outputs and outcomes.

### Future directions

- Continue the development of the WAHerb upgrade.
- Continue the development of *FloraBase* 3.
- Maintain the remaining applications and engage in the biodiversity informatics community.



### Taxonomy of undescribed taxa in the Ericaceae subfamily Styphelioideae, with an emphasis on those of conservation concern

SP 2011-015

M Hislop

### Context

Recent phylogenetic studies have resulted in significant changes to the classification of the epacrids at the generic level. The circumscription of the genus *Styphelia* has now been expanded to include all taxa previously in *Astroloma*, *Coleanthera* and *Croninia*, as well as a large percentage of those that were in *Leucopogon*. A recent publication formalising these changes has opened the way to the process of describing the many phrase name taxa of *Styphelia* (i.e. in the newly expanded sense) that are currently listed under *Leucopogon*. A significant number of these are short range endemics of conservation significance. In addition there is still much taxonomic work remaining to do in *Leucopogon s. str.*

### Aims

- Publish new taxa from the tribes *Styphelieae* and *Oligarrheneae*, prioritising those of high conservation significance.
- Continue a taxonomic assessment of species boundaries across the tribe *Styphelieae* (mainly in *Leucopogon* and *Styphelia*) with a view to identifying previously unrecognised taxa, especially those that may be geographically restricted.

### Progress

- A collaborative nomenclatural paper formalising the transfer to *Styphelia* of species currently in *Leucopogon*, *Astroloma*, *Coleanthera* and *Croninia*, has been published in *Australian Systematic Botany*.
- A collaborative paper on the taxonomy of the *Styphelia xerophylla* species group has been published by *Nuytsia*. This includes four new species, all of which are of conservation significance.
- A paper describing two anomalous and geographically restricted new species of *Styphelia* has been published in *Nuytsia*.
- A paper dealing with the taxonomy of the *Styphelia intertexta* species group has been published in *Swainsona*. This includes two new species, both of conservation significance.
- A new geographically restricted species of *Leucopogon* has been published in the *Nuytsia* 50<sup>th</sup> special anniversary edition.

## Management implications

- The epacrids, of which *Styphelia* (in the newly expanded sense) and *Leucopogon* are by far the largest genera, have a major centre of diversity in south-west Western Australia. An authoritative source of current information is fundamental to correctly managing the conservation taxa and the lands on which they occur for this taxonomically difficult group that is also very susceptible to a number of major threatening processes, including salinity and *Phytophthora* dieback.

## Future directions

- Preparation of further papers describing new taxa mostly in *Styphelia* and *Leucopogon*.
- Further field studies to assist in the taxonomic resolution of potentially new taxa in the tribe *Styphelieae*.



## Resolving the systematics and taxonomy of *Tephrosia* in Western Australia

SP 2011-002

R Butcher, T Macfarlane

## Context

*Tephrosia* is a large, pantropical legume genus comprising about 400 species of herbs and shrubs. Sixty-five taxa are currently recognised in the Eremaean and Northern Botanical Provinces of Western Australia, including 26 phrase-named taxa, with a number of species complexes requiring further study. *Tephrosia* specimens are frequently collected during vegetation surveys for proposed mining developments in northern Western Australia; however, many of them cannot be adequately identified as they belong to poorly-known, undescribed taxa or to species complexes. Their identification is further hindered by the absence of up-to-date taxonomic keys and of comparable specimens, as many species of *Tephrosia* grow in remote areas and are poorly collected. Identification difficulties inhibit the accurate assessment of each taxon's distribution and hence its conservation status.

## Aims

- Resolve the taxonomy of *Tephrosia* in Western Australia and Northern Territory using morphological and molecular approaches.
- Assess the conservation status of all Western Australian taxa.
- Prepare an electronic Flora treatment of the genus in Western Australia and Northern Territory (for the *eFlora of Australia*).
- Prepare identification tools, including an electronic key to the genus.
- Contribute to international phylogenetic research on *Tephrosia* and allied genera.

## Progress

- One species description was published in *Nuytsia* and a paper was submitted.
- Two taxonomic papers, in which four new species are described and three species are recircumscribed, have been completed and two are near completion.
- One taxon (*T. sp.* Glenormiston), recognised for Queensland and recently for the Northern Territory, was also identified as occurring in Western Australia and South Australia.
- *eFlora* profile pages for all project-relevant taxa have been established.
- Two weeks were spent at the National Herbarium of Victoria annotating specimens to improve *Australasian Virtual Herbarium* data quality.
- Three months were spent at the Queensland Herbarium studying and curating the collection, preparing descriptions for new and revised taxa, and sampling specimens for molecular analysis.
- Fifteen informal names unknown to Western Australia and Northern Territory were applied to specimens collected from these jurisdictions; these were studied and complexes identified.
- Large specimen loans were received to aid resolution of three pan-Australian complexes.



- A total of 36 samples for molecular analysis were processed and sent to overseas collaborators. These represented 25 unsampled Queensland taxa; the molecular phylogenetic study now contains most Australian species.
- Ongoing curation of the Western Australian Herbarium's research and reference collections and ImageBank images was undertaken.

### Management implications

- Providing names, scientific descriptions, illustrations and identification tools for the various *Tephrosia* in Western Australia will enable industry and conservation practitioners to accurately identify taxa, thereby improving their management and the assessment of their conservation status. If it is found that the individual *Tephrosia* taxa can be identified through DNA barcoding, this method will enable sterile or poor specimens, often collected during botanical surveys, to be accurately identified.
- Collaborative research with *Tephrosia* experts in Northern Territory and Queensland, will allow novel forms collected in Western Australia to be more readily and rapidly identified as either first records for the State of taxa occurring elsewhere in Australia, or as taxa truly new to science. This will prevent the proliferation of superfluous names on the vascular plant census, improve the accuracy and utility of the *Australasian Virtual Herbarium*, and increase certainty for stakeholders.

### Future directions

- Review variation in existing named taxa occurring in Western Australia and Northern Territory, revise descriptions where necessary, and publish papers describing new species.
- Complete production of a revisionary treatment of *Tephrosia* in Western Australia and Northern Territory for the *eFlora of Australia*, and a key to all *Tephrosia* taxa in those jurisdictions.



### Taxonomy of selected families including legumes, grasses and lilies

SP 2011-001

T Macfarlane

### Context

Successful conservation of flora requires that conservation units equate to properly defined, described and named taxa. There are numerous known and suspected unnamed taxa in the grass, legume and 'lily' (now Asparagaceae, Hemerocallidaceae) families, as well as numerous cases where keying problems or anomalous distributions indicate that taxonomic review is required. This is true of various parts of the families but the main current focus is on *Althenia* (formerly *Lepilaena*), *Thysanotus*, *Wurmbea*, *Lomandra*, *Neurachne* and *Trithuria*.

### Aims

- Identify plant groups where there are taxonomic issues that need to be resolved, including apparently new species to be described and unsatisfactory taxonomy that requires clarification.
- Carry out taxonomic revisions using fieldwork, herbarium collections and laboratory work, resulting in published journal articles.

### Progress

- *Althenia* - A paper with a new Western Australian species has been submitted to *Phytotaxa*. Molecular phylogenetic results support the distinction of the new species from currently known species. The new species is not considered threatened.

- *Wurmbea* - Work included processing of newly collected herbarium material ready for study, further work on an identification key and preparation of photographic plates for use in papers. A paper describing a new species is in press with *Nuytsia*.
- Hydatellaceae - Field surveys continued on *Trithuria australis*, and a study of two fruit forms in *T. bibracteata* may indicate the existence of two species under this name.
- *Thysanotus* - Taxonomic study of the twining stemmed *T. patersonii* group continued with field work, herbarium study and preparation of photographic plates in preparation for publication. Field work included a Wheatbelt area with poor collecting history for potentially threatened species and a survey of the Shark Bay to Murchison area, providing new collections, data and one new species. A paper describing a new species (non-twining) from Kalbarri was published in *Nuytsia*. A field survey was conducted on the conservation priority species *T. formosus*.
- *Corynotheca* - A taxonomic revision is near completion following further herbarium study.
- Asparagales - A collaborative phylogenetic study of the Australian Asparagaceae subfamily Lomandroideae using DNA sequence data and morphology was published in *Molecular Phylogenetics and Evolution*. The main groups of genera were supported as monophyletic except that the Western Australian *Xerolirion* is included in *Lomandra*. These main generic groups differ in floral biology, life form and possession of storage organs, showing that these features were established early in the evolution of the subfamily and they represent fundamental differences in their biology. A more detailed molecular phylogeny of the genus *Lomandra* is treated in another paper in preparation, which generally supports known groupings of species but with some interesting new relationships suggested.
- Poaceae - A multidisciplinary paper investigating the mechanisms of development of C<sub>4</sub> photosynthesis from C<sub>3</sub> in *Neurachne* published in *Plant Physiology* revealed that *N. annularis* is a previously unsuspected photosynthetically intermediate species, making it of evolutionary and possibly practical interest. Samples were provided to the Plant and Fungi Tree of Life project at the Royal Botanic Gardens, Kew, UK.
- Anarthriaceae - A paper describing male reproductive development as a follow-up to a previous study of female structures is in preparation with collaborators. At the species level, the widespread species *Anarthria gracilis* has been found to actually comprise three species. A paper presenting these findings based on field study, morphology and DNA analysis is also in preparation.
- Priority conservation species - A set of five papers was written, describing species for a special series of *Nuytsia*.

### Management implications

- Identification of species known or suspected to have a restricted distribution will enable re-assessment of the conservation status and improve management effectiveness. Improved identification tools will enable more effective and reliable identification of species and the subsequent assessment of their conservation status. Better knowledge of plant relationships adds to appreciation of the global significance of the Western Australian flora and facilitates its appropriate representation in a wide range of research.

### Future directions

- Complete and submit papers describing new species of *Wurmbea*, *Thysanotus*, *Lepilaena* and *Lomandra*.
- Conduct appropriate field searches for species or populations of relevant families that are insufficiently known.
- Continue to revise plant groups and investigate via field and herbarium studies various putatively new species in order to improve knowledge of the flora, provide stable plant names, and provide a means of identifying species.
- Publish and present information on selected plant groups for general audiences.



## Systematics of the triggerplant genus *Stylidium*

SP 2010-001

J Wege

### Context

With more than 300 known taxa, the triggerplant genus *Stylidium* is one of the most abundant and diversified genera in Australia. While substantial progress has been made over the past 20 years in documenting Australia's *Stylidium* diversity, our knowledge of the genus remains insufficient for scientific and conservation needs. There are new taxa awaiting formal description, species complexes that remain poorly understood, and a number of nomenclature and typification issues that require resolution. Perhaps the most significant issue at this point in time is the lack of an overarching flora treatment for the family Stylidiaceae, which hinders accurate identification by conservation personnel, botanical consultants and other stakeholders. This is concerning given the high proportion of taxa that require further survey to understand the full extent of their distribution and their conservation requirements.

### Aims

- Improve the underlying taxonomic knowledge necessary for effective biodiversity management of the triggerplant family Stylidiaceae and make this information readily accessible to stakeholders.
- Investigate phylogenetic relationships within *Stylidium* and use these data to inform taxonomic research and conservation management.

### Progress

- A taxonomic revision of the Australian endemic genus *Levenhookia* (12 spp.) was completed and published in *PhytoKeys*. It includes the description of *L. aestiva*, a novel species from south-western Australia, and identification guides to all species. *Levenhookia preissii* was added to Western Australia's *Threatened and Priority Flora list* as a direct outcome of this research.
- Descriptive data were compiled for a number of northern Australian triggerplants, including two undescribed species. Preliminary observations were also captured on species complexes in need of further taxonomic research. Two new populations of the endangered species *S. elachophyllum* were discovered.
- A research visit to the National Herbarium of Victoria focussed on locating and annotating type material, updating specimen identifications, and extracting data from spirit and pressed collections to support future publications.
- The treatment of Stylidiaceae for *Flora of Australia* has been progressed with preparation of several taxonomic manuscripts in which novel taxa will be described and nomenclatural issues resolved.

### Management implications

- Herbarium-based taxonomic research and targeted field work continue to improve our understanding of the distribution, habitat requirements and conservation status of Australia's triggerplant flora.

### Future directions

- Continue writing species profiles for the *Flora of Australia*.
- Continue taxonomic validation of specimens housed at Australian herbaria.
- Conduct targeted field work to advance research publications and the *Flora of Australia* treatment.
- Prepare publications describing novel taxa, resolving typification issues, and documenting evolutionary relationships.



## Taxonomic review and floristic studies of the benthic marine algae of north-western Australian and floristic surveys of Western Australian marine benthic algae

SP 2009-009

J Huisman, C Parker

### Context

This project involves systematic research into a poorly known group of Western Australian plants and is directly relevant to the department's nature conservation programs. It includes floristic studies of the marine plants of several existing/proposed marine parks and also areas of commercial interest (Shoalwater, Marmion, Ningaloo, Dampier Archipelago, Barrow Island, Montebello Islands, Rowley Shoals, Scott Reef, Maret Islands, etc.) to provide baseline information that will enable a more comprehensive assessment of the Western Australian marine biodiversity.

### Aims

- Collect, curate and establish a collection of marine plants representative of the Western Australian marine flora, supplementing the existing Western Australian Herbarium collection.
- Assess the biodiversity of the marine flora of Western Australia, concentrating initially on the poorly-known flora of the tropics.
- Prepare a marine flora guide for north-western Australia, documenting this biodiversity.

### Progress

- The book *Marine Plants of Australia* (revised edition) was published by UWA Publishing. This book includes descriptions and *in-situ* colour images of over 600 species.
- The description of *Champia patula* appeared as part of the *Nuytsia* special edition and a further new species *Leptofauchea lucida* will be published.
- A third new species of marine algae, *Pseudoderbesia eckloniae*, was described for a filamentous chlorophyte from Cape Peron. This represents a new genus record for Western Australia.
- Major chapters describing marine plants authored for the book *Tropical Marine Life of Australia*.

### Management implications

- Easier identification of marine plant species leads to a more comprehensive understanding of their conservation status, recognition of regions with high biodiversity and/or rare species, recognition of rare species, recognition of potentially introduced species, and discrimination of closely-related native species.
- Enhanced knowledge of marine plant species allows a more accurate assessment of management needs and potential impacts of environmental change, including change conferred by resource developments, biosecurity breaches and climate change.

### Future directions

- Further surveys of the marine algae of Western Australia including at Coral Bay, the Capes region in the south-west of Western Australia, and sites in the Perth region including Cape Peron and Rottnest Island.
- Publication of papers describing new and existing genera, species and other categories.
- Finalise a monograph of the Western Australian species of the red algal genus *Champia*.
- Undertake further taxonomic studies of the potentially invasive red algal genus *Hypnea*.
- Undertake taxonomic assessments of poorly known species of the genus *Callithamnion*.



## The Western Australian marine benthic algae online and an interactive key to the genera of Australian marine benthic algae

SP 2009-008

J Huisman, C Parker, O Nazarova

### Context

This project is a direct successor to the *Western Australian Marine Plants Online* and will provide descriptions of the entire Western Australian marine flora as currently known, accessible through *FloraBase*. Interactive keys enable positive identification of specimens and provide a user-friendly resource that enables the identification of marine plants by non-experts. It will be of great value in systematic research, teaching, environmental and ecological research, and additionally in environmental monitoring and quarantine procedures.

### Aims

- Prepare an interactive key to the approximately 600 genera of Australian marine macroalgae.
- Provide online descriptions of the Western Australian marine flora, including morphological and reproductive features, to enable easy comparison between species.
- Provide online descriptions of higher taxa (genus and above).
- Incorporate descriptions and images of newly described or recorded taxa of marine flora into *FloraBase*.

### Progress

- Descriptions of 542 taxa (family, genus and species level), sourced from *Algae of Australia: Marine Benthic Algae of North-western Australia, 2. Red Algae* (Huisman 2018), have been formatted for inclusion in *FloraBase*.
- Over 600 fact sheets have been prepared for inclusion in the interactive key, including links to relevant external resources.
- Numerous additional *in situ* (particularly from the Perth region) and microscopic images of marine algae have been taken. Over 70 new images have been uploaded to ImageBank/*FloraBase*.
- Data for 427 algal specimens newly added to the Western Australia Herbarium collection are now available via *FloraBase*, significantly improving taxonomic and distribution knowledge concerning the Western Australian marine flora.
- A total of 199 current published native marine algal species names have been added to WACensus and 5,515 existing WAHerb records have been edited (associated with synonymy, cited specimens, and family changes).

### Management implications

- Easier identification of marine plant species will lead to a more accurate understanding of their conservation status, and enhanced knowledge of marine biodiversity that will permit a more accurate assessment of management proposals/practices and threats to biodiversity.
- Provision of a readily available web-based information system will facilitate easy access by managers, researchers, community and other marine stakeholders to marine plant species inventories and up-to-date names.

### Future directions

- Further refinement and completion of the interactive key.
- Continue collating existing species descriptions and write new descriptions for uploading to *FloraBase*.
- Upload additional marine plant images to ImageBank/*FloraBase*.



## Taxonomic resolution and description of new plant species, particularly priority flora from those areas subject to mining in Western Australia

SP 2009-006

J Wege, K Shepherd, M Hislop, B Rye, T Macfarlane, R Davis, S Dillon, R Butcher, C Wilkins

### Context

Western Australia has a rich flora that is far from fully known. New species continue to be discovered through the taxonomic assessment of herbarium collections, floristic surveys and the botanical assessment of mineral leases. There are more than 1,150 putatively new and undescribed taxa on Western Australia's vascular plant census, around half of which are poorly known, geographically restricted and/or under threat (i.e. threatened or priority flora). The lack of detailed information on these taxa makes accurate identification problematic and inevitably delays the department's ability to survey and accurately assess their conservation status.

### Aims

- Resolve the taxonomy and expedite the description of manuscript or phrase-named plant taxa, particularly threatened and priority flora and those taxa vulnerable to future mining activities.

### Progress

- A golden anniversary edition of *Nuytsia* has been prepared and publication is well underway - 25 out of a planned 50 new Western Australian species have been published, a majority of which are poorly known. Social media is being used to promote this unique initiative, with articles also written for *Landscape*, *Bushland News* and the newsletter of the *Australian Flora Foundation*.
- Ten additional conservation-listed taxa in *Styphelia* and *Isopogon* were published in *Swainsona* or *Nuytsia*, and a key to the species of *Thomasia* was also published in *Nuytsia*.
- A small amount of targeted field work to obtain type material or progress research on undescribed, conservation-listed taxa was conducted.
- Nine poorly known species from the genera *Acacia*, *Convolvulus*, *Darwinia*, *Gomphrena*, *Leucopogon*, *Microcorys* and *Swainsona* were discovered and added to the State's vascular plant census under phrase names.
- Expanded circumscriptions of *Goodenia* and *Styphelia* were published in *PhytoKeys* and *Australian Systematic Botany* respectively and include name changes for 17 conservation-listed taxa from Western Australia.

### Management implications

- The provision of names, scientific descriptions, illustrations and associated data will enhance the capacity of conservation and industry practitioners to identify new species, thereby improving species management, conservation assessments and land use planning.

### Future directions

- Identify and formally describe new taxa of conservation significance.



## Genetic and ecological viability of plant populations in remnant vegetation

SP 2002-001

M Byrne, C Yates, S McArthur

## Context

A priority for long-term conservation of remnant vegetation is the maintenance of viable plant populations. However, little is currently known about what biological factors actually affect population persistence. This project quantifies genetic and ecological factors that influence the viability of plant populations in fragmented Western Australian agricultural landscapes and explores how these are affected by remnant vegetation characteristics such as size, shape, isolation, disturbance and landscape position.

## Aims

- Identify and quantify the genetic and demographic factors that affect the viability of plant populations in vegetation remnants. The focus will be on the effects of genetic erosion, inbreeding and pollinator limitation on seed production and seedling fitness.
- Examine and model the relationships between key genetic and demographic factors affecting viability and remnant vegetation characteristics, such as size, disturbance and landscape position.
- Develop specific genetic and demographic guidelines for management of remnant populations of the target taxa and general landscape design principles for major plant life-history types that will maximise the probability of population persistence.
- Develop an understanding of the population biology, mating systems and gene flow of flora with distributions centred on the seasonally wet Busselton ironstone communities to inform management for long-term conservation in relation to population viability (population size and degree of connection) and appropriate fire frequency.

## Progress

- A paper on the reproductive biology and demography in *B. nivea* subsp. *uliginosa* has been published in *Botanical Journal of the Linnean Society*.

## Management implications

- The ability to rapidly and accurately assess the conservation value of a vegetation remnant is a critical step in landscape management aimed at integrating the goals of conservation and agricultural production. Currently much of this assessment is based on best guesses using anecdotal species-specific evidence, on the general principle that bigger is better, and on simple presence and absence data that take little account of long-term remnant trajectories. Improved accuracy of assessment of long-term persistence of broad classes of plant species will facilitate improved prioritisation of remnants for conservation and therefore better allocation of limited management resources.
- Establishment of realistic empirically-based goals for remnant size, shape and landscape configuration that maximise regional persistence of plant species will allow more efficient conservation efforts at the landscape level by facilitating cost-benefit analyses for remnant management and restoration work.

## Future directions

- This project has been completed.



## Translocation of critically endangered plants

SP 2001-004

L Monks, R Dillon, C Yates, M Byrne

## Context

The contribution of translocations (augmentation, reintroductions, introductions) of threatened flora to the successful recovery of species requires development of best-practice techniques and a clear understanding of how to assess and predict translocation success.

## Aims

- Develop appropriate translocation techniques for a range of critically endangered and other threatened flora considered a priority for translocation.
- Develop detailed protocols for assessing and predicting translocation success.
- Establish a translocation database for all threatened plant translocations in Western Australia.

## Progress

- An experimental translocation of *Lambertia orbifolia* was planted to assess fitness consequences of mixing genetically divergent lineages and the potential for increasing genetic diversity in translocated populations through genetic rescue.
- Monitoring was undertaken for a threatened ecological community associated with the translocation of *Banksia cuneata*.
- Analysis of flora translocation data from 22 years of plantings was undertaken to examine factors that contribute to translocation success.

## Management implications

- Translocations lead to improved probability of persistence for threatened flora, particularly critically endangered plant species. Ongoing monitoring of translocations is providing information on the success of methods used and the probability of long-term success. Close collaboration with departmental staff enables this information to be used immediately to inform other flora translocation projects.
- Further development of success criteria and methods for analysing long-term success, such as the use of Population Viability Analysis (PVA), mating system analysis and genetic variability analysis, will ensure completion criteria are adequately addressed and resources can confidently be re-allocated to new translocation projects.
- The improved awareness of best-practice translocation methods for departmental staff and community members undertaking such work, leads to greater translocation success.

## Future directions

- Finalise and publish meta-analysis on translocation methodologies, outcomes and success in Western Australia.
- Publish paper on *Lambertia orbifolia* genetics and mating systems study.
- Develop PVA model for translocated and natural populations of *Acacia cochlocarpa* subsp. *cochlocarpa* using demographic data already collected.
- Develop and implement a plan for the establishment of multi-species seed orchard sites for threatened Stirling Range plant species impacted by fire and *Phytophthora* dieback.



### **Mating system variation, genetic diversity and viability of small fragmented populations of threatened flora, and other key plants of conservation importance**

SP 2001-001

M Byrne, S McArthur, L Monks, R Dillon

## Context

Understanding the interaction between mating systems, levels of inbreeding and patterns of genetic variation within populations of species is a key element in assessing the viability of plant populations, particularly rare and threatened taxa, and the development of management strategies that reduce the likelihood of local extinction and increase the probability of successful establishment of restored populations.

## Aims

- Assess the relationship between effective population size and levels of genetic diversity, and the minimum effective population size for maintaining genetic diversity in natural and restored populations.



- Assess the effects of population size and habitat degradation on mating system parameters that indicate inbreeding or the potential for inbreeding.
- Assess whether reduction in population size, increased inbreeding and reduced genetic variation are associated with any reduction in fitness.
- Assess whether there are differences in the levels of genetic diversity and mating system parameters between rare and common congeners, which will provide a more general understanding of rarity in this flora and how it can be managed.

### Progress

- Data analysis has been completed for two translocated *Banksia brownii* populations and seven natural populations to assess mating system variation and genetic diversity, and benchmark mating system performance and genetic diversity in the translocated populations. A manuscript is near completion.
- Data analysis is being undertaken for pollination studies on *B. brownii* at one montane and two lowland populations, and one translocated population, to assess pollination adequacy in the translocated population and suspected differences in pollinator type between montane and lowland populations.
- Assessment of fitness trait studies are ongoing in a common garden experiment involving 1,100 seedlings of *B. brownii* from montane and lowland populations, and a translocated population, to examine trait differences between montane and lowland populations, and implications for population mixing, and to benchmark the performance of the translocated population.
- Analysis of data from a genetic diversity study and crossing study on the critically endangered *Schoenia filifolia* subsp. *filifolia* and another subspecies is underway. These studies aim to evaluate the level of genetic differentiation between subspecies and whether genetic rescue involving crossing between subspecies is a feasible management option.
- Genotyping and data analysis has been completed on three translocated and nine natural populations of *Lambertia orbifolia*. Genotyping will enable the assessment of mating system variation and genetic variability, and benchmark mating system performance and genetic diversity in translocated populations. A manuscript is near completion.
- Data analysis is underway on genetic diversity data for natural and translocated populations of *Acacia cochlocarpa* subsp. *cochlocarpa* and *A. cochlocarpa* subsp. *velutinos*. This study will benchmark genetic diversity in translocated and natural populations of *A. cochlocarpa* subsp. *cochlocarpa* and assess genetic structure across the range of both subspecies.
- Analysis of genotyping and mating system data for *B. anatona* is complete to assess mating system performance and genetic diversity in a translocated population compared to natural populations. A manuscript describing this study is near completion.

### Management implications

- Assessment of genetic variation and mating system parameters will inform prescriptions for the prevention of inbreeding and maintenance of genetic variation in small fragmented populations of rare and threatened plants, and will facilitate strategies for managing inbreeding and loss of genetic diversity during translocation programs involving species such as *B. brownii*, *L. orbifolia*, *A. cochlocarpa* and *S. filifolia*.

### Future directions

- Finalise mating system and genetic diversity analyses on translocated and natural populations of *B. brownii*, *L. orbifolia*, *A. cochlocarpa* and *S. filifolia*.



### The population ecology of critically endangered flora

SP 2000-015

C Yates, C Gosper

## Context

South-west Western Australia is a global hotspot of plant diversity. Determining the relative importance of multiple threatening processes, including the interactions between fragmentation and small population processes, fire regimes, weed invasion and grazing regimes, is critical for conservation and management of threatened flora and threatened ecological communities.

## Aims

- Determine the critical biological factors and the relative importance of contemporary ecological interactions and processes that limit population viability and persistence of threatened flora, particularly critically endangered species and other key plant species occurring in threatened ecological communities (TECs).

## Progress

- Continued monitoring the Eastern Stirling Range Montane Heath and Thicket TEC and associated threatened flora to assess impacts and recovery following the May 2018 bushfire.
- Monitored an experiment investigating the influence of vertebrate grazing and fire interval on the recovery of the critically endangered *Banksia anatona* following the May 2018 bushfire in Stirling Range National Park.
- Continued monitoring the demography of the critically endangered *Banksia verticillata* and the impact of fire in Torndirrup National Park.
- Completed a population viability analysis of *B. verticillata* investigating the relative roles of canker disease, fire-interval and fire patchiness in the taxon's observed decline. A paper is being prepared.
- Continued monitoring the effect of invasive bulb invasion and the effect of invasive bulb control methods on the population dynamics of the critically endangered *Ptilotus pyramidatus* on the Swan Coastal Plain.
- Commenced an experiment testing the effect of a novel herbicide to control invasive African lovegrass on native flora, including the endangered *Grevillea curviloba*
- Completed a regional analysis of the spatial distribution of threatened and priority flora and major threatening processes in the Southwest Australian Floristic Region (SWAFR). A paper has been submitted for publication.
- Completed a review of published literature to determine the influence of evolutionary, genetic and ecological traits on susceptibility of the flora to major threatening processes in the SWAFR. A paper has been submitted for publication.
- Published a paper in the *Australian Journal of Botany* on the pollinator community and pollination biology of four threatened *Tetradthea* taxa from Banded Iron Formation (BIF) Ranges in the Yilgarn.

## Management implications

- Demographic studies, models and experiments investigating the impact of fire regimes, plant disease and vertebrate grazing for the Montane Heath and Thicket TEC and threatened flora of the South Coast Region will provide critical information for defining ecologically acceptable fire return intervals and species recovery.
- Demographic studies and experiments investigating the impact of environmental weeds on *P. pyramidatus* and *Grevillea curviloba* will provide critical information for supporting species recovery.
- Analysis of the spatial distribution of threatened and priority flora in the SWAFR found that conservation significant flora have smaller geographic ranges than other flora, and have populations disproportionately distributed on old, climatically buffered, infertile landscapes and on surface geologies of limited extent, thus highlighting hotspots for management.
- Evolutionary history contributes to both the extent of exposure of the flora to threatening processes, and the susceptibility of the flora to those threats via natural selection over evolutionary time filtering the distribution of plant traits. Consideration of evolutionary history has an important role in informing conservation management.
- Knowledge of the pollinator community and pollination biology of *Tetradthea* taxa from BIF, some of which are threatened by mining, will provide critical information for conservation.

## Future directions

- Continue demographic studies investigating fire regime, disease and vertebrate grazing impacts and recovery actions for threatened flora with South Coast Region including the recent 2019 bushfire in the

eastern Stirling Ranges.

- Continue demographic studies investigating environmental weed impacts and recovery actions for threatened flora with Swan Region.
- A paper investigating the role of canker pathogen and fire regimes in the decline of *B. verticillata* will be completed and published.
- Complete journal publications on the spatial distribution of threatened and priority flora in the SWAFR and the role of evolutionary history in mediating exposure and susceptibility of the flora to threats.
- Complete the analysis intersecting threatened and priority flora distribution with the spatial distribution of threatening processes in the SWAFR.



### Seed biology, seedbank dynamics and collection and storage of seed of rare and threatened Western Australian taxa

SP 1999-010

A Crawford, A Monaghan

#### Context

Seed conservation is a specific and targeted action to conserve biodiversity and entails the banking of genetic material in the form of seed. Seed banking provides an important opportunity for assessing and utilising genetic material for *in situ* recovery actions, and for seed research. Understanding the seed biology and ecology of plant species is important for the conservation and management of conservation-significant Western Australian taxa and for developing and implementing recovery plans for rare and threatened flora.

#### Aims

- Provide a cost effective and efficient interim solution to the loss of plant genetic diversity by collecting and storing seed of rare and threatened Western Australian plant species, and thereby provide a focus for flora recovery.
- Increase knowledge of seed biology, ecology and longevity.
- Incorporate all information into a corporate database and provide relevant information on seed availability, seed biology, storage requirements and viability of seed of rare and threatened taxa to assist the development of management prescriptions and preparation of interim recovery plans and translocation plans.

#### Progress

- A total of 97 seed collections (64 species) were banked at the Western Australia Seed Centre (Threatened Flora Seed Vault); 71 of these collections (42 species) were listed as critically endangered, endangered or vulnerable (threatened flora). Nine of these collections (five species) were listed as priority flora.
- One hundred and forty germination tests were conducted.
- Seedlings of 10 threatened flora species were provided for translocation.
- Two species (*Schoenia filifolia* subsp. *subulifolia* and *Ptilotus pyramidatus*) were planted into a seed production area at Woodlupine Primary School.
- The seed bank now contains 5,923 collections (1,941 taxa) representing 344 threatened flora, 730 priority flora and 867 restoration species.
- Research into the storage performance of seed collections from 28 species (53 collections) that had been in storage for a period of at least 25 years was completed.

#### Management implications

- Seed conservation supports the survival of species in the wild by providing the genetic material for reintroduction; seed is provided for translocations of threatened flora and for departmental restoration projects.

- Provision of seed biology and ecology data increases the success of threatened flora recovery actions, particularly through knowledge of how pre-treatments may stimulate seed germination.

### Future directions

- Ongoing collection of seed of threatened flora for long-term conservation and use in translocations.
- Secure seed of conservation significant Western Australian native plant species potentially susceptible to myrtle rust prior to disease occurrence.
- Seed collection to assist Stirling Range threatened flora post fire recovery.
- Germinate seed of ten threatened Stirling Range species to facilitate translocation to assist with post fire recovery.
- Complete a review of the long-term (>10 year) storage performance of seed collections held in the Western Australian Seed Centre.



### Genetics and biosystematics for the conservation, circumscription and management of the Western Australian flora

SP 1998-003

M Byrne, R Binks, D Bradbury, B MacDonald, C Gosper, T Hopley, M Millar

### Context

The flora of Western Australia is complex due to the antiquity of the landscape, and this can lead to obscurity in taxonomic identity, which impacts on the conservation status of rare and threatened taxa. Genetic analysis can inform the conservation and biosystematics of these taxa.

### Aims

- Provide genetic information for the conservation and management of Western Australian flora, especially rare flora.
- Determine the phylogenetic and population genetic relationships among the disjunct populations of *Eucalyptus virginea* and related species, including the potential hybrid status of *E. x phylacis*.
- Determine the phylogenetic relationships among Western Australia *Leptospermum* species and examine the genetic boundaries among several species complexes.
- Determine the potential for hybridisation and genetic differentiation among *Seringia exastia*, *S. katatona*, *S. elliptica* and *S. nephrosperma*.
- Determine the geographic range of two identified genetic lineages within *Eucalyptus salubris* and investigate genomic relationships among nine species within the gimlet complex.
- Investigate potential hybrid origins and parental sources of several *Eucalyptus* entities within the Stirling Ranges.
- Determine the genetic relationship between *Verticordia spicata* subsp. *spicata* and the critically threatened *V. spicata* subsp. *squamosa*.
- Determine the genetic relationship between populations of *Davesia obovata* in the Stirling Ranges and Fitzgerald River National Park.
- Determine the genetic relationships among several subspecies and unnamed entities within *Conospermum caeruleum*.
- Determine the genetic relationship among disjunct populations of *Banksia mimica* and the degree of clonal reproduction in different populations.
- Investigate the role of lignotuber loss or gain in the evolution and conservation of eucalypt diversity, through deriving phylogenetic relationships and quantifying genetic differentiation among a clade of eucalypts with obligate-seeder and lignotuber-resprouter taxa, using high density, genome-wide markers.
- Determine the genetic diversity and differentiation among sub populations of *Marianthus aquilonaris* in the Bremer Range.

## Progress

- Genomic analysis of *E. virginea* and related species confirmed the identification of the disjunct population of *E. virginea* in Meelup and the status of *E. phylacis* as an F1 hybrid between parents, *E. virginea* and *E. decipiens*. A paper detailing genomic assessment of the relationships among *E. virginea*, *E. relictata*, *E. lane-poolei*, and *E. x phylacis* has been prepared for submission to *Biodiversity and Conservation*.
- Phylogenomic analysis of eastern Australian *Leptospermum* taxa is ongoing. A paper detailing phylogenomic relationships in the *Leptospermum* genus, with a focus on Western Australian taxa, is in preparation. The analysis shows separation into four clades with other genera nested within indicating taxonomic revision is required.
- Field collections, sequencing and genomic analysis for the *L. erubescens* species complex has been completed. These data showed clear separation of *L. maxwellii* and a clinal relationship between *L. erubescens* and *L. oligandrum*.
- A paper combining the genomic analysis of the *S. exastia* species complex with subsequent taxonomic revisions has been published in *Taxon*.
- A paper detailing the genomic, morphological and ecological divergence of the cryptic lineages in *E. salubris* has been submitted to *Molecular Ecology*.
- Genomic analysis of the nine species of the gimlet complex is near completion.
- Genomic analysis is complete for the putative *Eucalyptus* hybrid entities in the Stirling Ranges. This study confirmed eight suspected hybrid combinations and identified the parental taxa involved. A paper has been submitted to *Annals of Botany*.
- Genomic analysis and morphological assessment of *V. spicata* has shown that there is a lack of evidence to support the continued recognition of *V. spicata* subsp. *squamosa* as a subspecies distinct from *V. spicata* subsp. *spicata*.
- Genomic analysis of *D. obovata* is underway. Preliminary analysis indicates strong differentiation between the disjunct Stirling Range and Fitzgerald River National Park populations.
- Field collections, sequencing and preliminary genomic analysis of the *C. caeruleum* species complex has been completed and a report has been written. Genomic data warrant the recognition of at least three distinct species, and three independent management units within the south-west species.
- Relationships among populations of *B. mimica* and the degree of clonal diversity within different populations has been determined using nuclear microsatellite markers. A paper detailing the strong differentiation among populations and variable clonality has been accepted for publication in *Conservation Genetics*.
- Taxonomic revision of *Eucalyptus* subseries *Levispermae* has been completed and published in *Nuytsia*.
- Analysis of gene flow among sub-populations of *M. aquilonaris* has been completed showing high levels of self-pollination and the majority of pollination occurring within the sub-populations, with little pollen dispersal between sub-populations despite close proximity. A report has been prepared.

## Management implications

- Population genetic analysis of relationships among disjunct populations of *E. virginea* provides information for management of the populations, and confirmation of the hybrid status of *E. x phylacis* provides information for management priorities.
- Assessment of the genetic relationships among *Leptospermum* species will inform taxonomic revision of the group, and define taxonomic entities to inform use of natural resources for honey production.
- Recognition of *S. x katarata* as a hybrid and synonymisation of *S. exastia* and *S. elliptica* mean that neither taxon meets the criteria for conservation listing.
- Resolution of lineages in *E. salubris* and genetic relationships among all nine species in the gimlet complex will provide a basis for potential taxonomic revision.
- Analysis shows lignotuber state is an important taxonomic character in eucalypts, supporting recognition as separate taxa for populations that differ in this trait.
- Identifying putative hybridisation within several *Eucalyptus* entities, including *E. erectifolia*, within the Stirling Ranges will allow for potential taxonomic revision and reconsideration of conservation listings.
- Resolution of the taxonomic status of *V. spicata* subspecies will allow re-assessment of the need for conservation listing of *V. spicata* subsp. *squamosa* and ongoing management of this subspecies.
- Population genetic analysis of *D. obovata* provides information for the management of these highly disjunct populations.
- Genomic analysis of the *C. caeruleum* subspecies will provide a basis for taxonomic revision of this highly morphologically variable group, particularly in regard to potential new taxa that may be threatened and

require conservation listing and management.

- Identifying genetic entities in *A. viscosa* and *A. tetandra* will provide a basis for taxonomic resolution of these species complexes.
- Strong genetic differentiation and variable degrees of clonal diversity among populations of *B. mimica* indicate taxonomic revision is required and provides information for population census counts and differing management of populations.
- High genetic differentiation over very short distances in *M. aquilonaris* provides information for assessment of the impact of disturbance on sub-populations of this species.

### Future directions

- Phylogenomic analysis of *Leptospermum* will be progressed and papers written.
- Fieldwork and population genomic analysis of a final *Leptospermum* species complex will be undertaken and a paper to delineate the major Western Australian taxa will be written.
- Genomic analysis of the gimlet complex will be completed and a paper written.
- A paper regarding the *V. spicata* subspecies will be written and the taxonomy revised.
- Further genomic analysis of *D. obovata* will be undertaken.
- Additional genomic analyses to further clarify relationships among south-west populations of *C. caeruleum* will be conducted, a paper will be written and the taxonomy revised.



## Ecosystem Science

**Program Leader: Adrian Pinder** Applied research undertaken by the Ecosystem Science Program seeks to understand the environmental, ecological and biogeographical processes that determine the conservation values, health and productivity of the lands and inland waters managed by the department. The program's research spans two broad themes: biogeography, and how ecosystems function and respond to threatening processes and management.

Biological surveys provide information on the composition of communities and distribution of the State's flora and fauna at scales relevant to management questions. Survey data provides the foundation for a range of management activities, including conservation estate planning, assessing the conservation status of species and communities and predicting the impacts of other land uses and threats.

The program investigates how ecosystems function and respond to water and land resource management practices and to broadscale threats including salinity, altered hydrology, climate change and habitat fragmentation. Projects include investigations into the nature of the threats through to monitoring associated ecological responses and effectiveness of mitigation strategies. The program also investigates genetic diversity, evolutionary history and ecological plasticity of plant populations in relation to guiding seed collection for restoration.

The program collaborates with other parts of the department, museums and herbaria, universities, cooperative research centres, natural resource management groups, CSIRO and other research providers. Partnerships also exist with traditional owners, resource companies and the environmental consulting industry.



### Investigating the causes of change in forest condition

SP 2019-048

K Ruthrof, D Tarrant, R Van Dongen

#### Context

A decline in vegetation density in the north-east of the forest management plan area was noted in *Mid-term review of performance of the Forest Management Plan 2014-2023*. The decline is broadly consistent with climate change predictions, although other factors may be contributing. Previous research suggests that *Eucalyptus wandoo* has been undergoing a series of declines associated with drought and increasing temperatures, and a Buprestid beetle (*Cisseis fascigera*). *Eucalyptus marginata* and *Corymbia calophylla* have been reported to be vulnerable to acute drought and heatwave events at water-shedding sites with shallow soils, as well as frost events.

More information is needed about the landscape, site and stand characteristics that predispose forest to decline. This project will build on the information available and investigate the contributing factors. This will provide a greater understanding of the vulnerability of the forest to climate change and assist in developing

evidence-based management interventions.

### Aims

- Investigate the cause of decline in vegetation density in south-west forests by understanding the interactions of contributing factors.

### Progress

- Estimates of vegetation cover derived from Landsat (i35 index) were used to create a stratified decline map of the forest over a 30 year period.
- Climate analysis suggests that decline is associated with lower rainfall for the previous year, and higher vapour pressure deficit over the past seven years.
- Analysis of decline sites compared with control sites (with a relatively stable vegetation cover) indicated that fire and aspect may be implicated in the decline.
- Particular vegetation types showed higher levels of decline than others, including sandy basins and granite outcrops. Preliminary site investigations suggest that, for example, *Banksia* woodland on deep, sandy soils, may be recovering more slowly following fire than other vegetation types.
- Preliminary results from the rapid field assessment suggest that larger canopy trees are experiencing higher levels of canopy reduction in decline sites, compared with control sites.

### Management implications

- Knowledge gained from this study can be incorporated into forest management policy and planning, and contribute to the mapping of forest health and reporting for the next forest management plan.

### Future directions

- Using the methods developed for investigating decline in the north-east forest, examine decline correlates in the forest further south.
- Undertake further field work in declining and stable sites to investigate stand and plant variables associated with decline.
- Continue to investigate the time of recovery needed by forest ecosystem types from a range of fire frequencies and fire severities.
- Investigate increasing the accuracy of mapping of the *Banksia* woodland in the northern *Jarrah* forest.



### Do hotter and drier regions harbour adaptive variation for climate change?

SP 2017-022

M Byrne, K Ruthrof, R Mazanec

### Context

Understanding the capacity of trees to respond to climate change is essential for the maintenance of biodiversity, forest health and productivity. In south-west Australia, climate change has increased the frequency and intensity of droughts, which has resulted in tree death and negatively affected essential ecosystem services. Adaptive land management is required to mitigate the risk of large-scale drought mortality in a rapidly changing climate. Current forest regeneration practice provides for seed sourcing from land management units adjacent to the site based on a broad interpretation of local provenance in widespread semi-continuous species. Assisted gene migration has also been advocated as a tool for land managers and foresters in managing forests and establishing plantations for future climates, and a scientific basis is required for land-managers to make informed decisions regarding the implementation of assisted gene migration.



Marri (*Corymbia calophylla*) is an important component of the forest ecosystem providing nesting hollows and a food source for threatened cockatoo species. In addition to being an important timber tree, the fruit, seeds, flowers, leaves and wood of marri are all important sources of food for native fauna. The seeds are a major food source for nationally listed threatened birds (Baudin's black cockatoo and Carnaby's black cockatoo) and the maintenance of habitat and food resources is a key factor in forest management practice. In each of the forest and woodland ecosystems where marri is present, it is an important and integral keystone species. Consequently, a decline in its overall health, now being experienced due to drought and disease, will have significant long-term detrimental impacts on ecosystem function. Management of keystone species within forest ecosystems needs to have a strong scientific basis. This project will deliver a scientific basis for consideration of adoption of assisted gene migration in south-west forests, through a detailed understanding of genetic adaptation and physiological tolerance in marri, and the capacity for enhanced drought-resilience under future hotter and drier climates.

### Aims

- Characterise neutral and adaptive genetic variation to estimate demographic (population size, migration) and evolutionary (adaptation to climate) processes.
- Estimate the heritability of plant functional traits associated with growth and resilience, and correlated traits, to determine the propensity for genetic adaptation.
- Determine the physiological and molecular capacity to respond to drought to elucidate the mechanisms enabling plants to persist under climate change.

### Progress

- Genomic analysis across the range of marri identified that greatest variation was explained by associations with temperature rather than rainfall or aridity. Variation occurred throughout the genome, including in coding regions known to regulate processes important in stressful climatic conditions, suggesting that both adaptive and plastic responses are involved in the response of marri to climate. A paper on genetic adaptation to climate in marri has been published in *Molecular Ecology*.
- Analysis of provenance trials at Mt Barker and Margaret River showed moderate levels of genetic heritability for growth and disease, and strong associations with the climate of origin (temperature, rainfall). A paper has been published in *Evolutionary Applications*.
- Analysis of data from a drought experiment and a heatwave experiment has been completed. Results suggest that plants from cooler provenances exposed to the 46 °C heatwave experienced the most severe impacts on growth and had the highest levels of leaf damage. A paper has been prepared.

### Management implications

- Assisted gene migration has been suggested as a key climate change adaptation strategy for forests worldwide, and could be readily incorporated into current silvicultural practices in south-west forests through the inclusion of seed from dry adapted provenances in regeneration. This project will provide the scientific evidence required to determine effective assisted gene migration practices in south-west forests for resilience to changing climates, providing a basis for adoption of this practice by decision-makers and acceptance by the community and non-government organisations.
- Understanding of response of plant traits to changing climates will enable predictions and modelling of plant adaptation and strength of selection, and inform forest management in response to climate change.

### Future directions

- This project is completed with publications on glasshouse heatwave and drought experiments.



### Hydrological function of critical ecosystems

SP 2016-005

J Rutherford, G McGrath, B Huntley

## Context

Biodiversity conservation requires an understanding of ecological processes that include balances and fluxes of water, energy and biogeochemistry. These processes are considered in a number of coarse scale ecological assessment and management frameworks, but these frameworks are difficult to apply at finer, or local, scales where an appreciation of hydrological variation is important. To increase confidence in applying coarse scale management frameworks at finer scales they need to be verified by results from targeted, critical, local scale ecosystem investigations. Critical ecosystem sites are selected where dominant processes driving their behaviour are complex, but not unique, so that frameworks for ecosystems with similar hydrological function and response to change can be assessed. The project will investigate the hydrological function of local scale critical water dependent ecosystems, determine and improve our understanding of dominant hydrological processes controlling their physico-chemical sensitivity and responses to change, and feed the results back into coarser scale ecosystem management frameworks. Local scale sites will be selected where ecohydrological data can be collected and integrated with existing biophysical datasets and information to optimise the transferability of hydrological results and outcomes to other areas.

## Aims

- Assess and determine the scales and dimensions of data required to map hydrological features being researched and measure change important for interpretation and management.
- Build suitable conceptual hydrological models within the bounds of available data and application requirements.
- Explore critical hydrological parameter/system sensitivities to resolve potential ecohydrological management zones.
- Construct conceptual hydrological models and review the need and uncertainties associated with numerical models.

## Progress

- Fine scale hydrological monitoring of four Walyarta mound springs and Mandora Lake has been completed. The results have been interpreted and reported and provide new information to update the conceptual model. Key findings are that spring discharge rates are likely to be consistent throughout the dry and wet season and reductions in evapotranspiration, in the dry season, produces visible pools of water that make the springs important refuges.
- Two journal articles are being prepared for the Walyarta study. One covers the use of remote sensing methods to map and develop conceptual models to assess mound spring resilience. A second article examines the development of fine scale spring water balances using hydrological and geochemical models.
- A report and journal article are being prepared for the Brixton Street Wetlands that discusses the seasonality and dynamics of the claypan hydroperiods.
- Hydrological monitoring at Ashfield Flats has continued to assess the dominant hydrological processes responsible for the surface water in the reserve, the urban drain discharges into the Swan River and the groundwater interactions associated with heavy metal and nutrient pollutants. Surface water monitoring has led to the development of a numerical hydrological model to simulate the long-term hydroperiods temporally and spatially in the reserve. Water and sediment samples collected for analysis indicate particular contaminants and likely sources of that contamination. A report and journal articles are being prepared detailing the Swan River-wetland interactions, anthropogenic contamination of sediments and waters, and groundwater flow processes.

## Management implications

- The collection of fine scale hydrological data for the Walyarta mound springs provides the basis to develop water balances and understand the different water requirements for springs located in different hydrological settings.
- The approach used to investigate and assess the Walyarta mound spring water balances and determine their resilience under changed water availability are transferable to other spring locations in Western Australia. This will help with the provision of advice on appropriate methods to investigate and assess other springs that host threatened ecological communities (TECs).
- Knowledge of hydrological functioning of the Brixton Street wetlands will increase the department's capacity to develop actions to reduce environmental impacts on TECs, other significant ephemeral wetlands and

threatened flora on the Swan Coastal Plain. This will allow for the provision of more effective interagency advice on the potential environmental consequences of developing land within the Guildford Formation.

- Improved understanding of the Swan River - Ashfield Flats interactions will support the department's ability to develop strategies to manage the contaminated inflows at this site. More broadly, the study is developing methods to assess the hydrological functioning of estuarine salt flats which will support better planning to manage these TECs.

### Future directions

- Develop simple spring water balance models to assess and quantify the water requirements of different springs.
- Complete publication on development of a three dimensional (3-D) conceptualisation of the Walyarta mound springs hydrology.
- Complete a report and a journal article on the spatial and temporal variation observed in groundwater and surface water interactions in the Brixton Street wetlands.
- Finalise monitoring and experiments at Ashfield Flats and publish papers.



### Responses of aquatic invertebrate communities to changing hydrology and water quality in streams and significant wetlands of the south-west forests of Western Australia

SP 2015-017

A Pinder

### Context

Aquatic habitats in the south-west of Western Australia are increasingly threatened from changes in hydrology, water quality and fire as a result of the drying climate, historical and current land use, and water resource development. The south-west of Western Australia has had a significant reduction in rainfall since the 1970s and it is predicted that by 2050 there will be little stream inflow into water supply dams. There is an inadequate understanding of the responses of aquatic communities to these threats to inform the management of many aquatic systems in the Forest Management Plan (FMP) area, including wetlands within the Muir-Byenup System Ramsar site. This project has two components, 1) re-survey of aquatic invertebrates in the Muir-Byenup System Ramsar site sampled in 1994 and 2004, addressing KPI3 of the 2014-23 FMP and, 2) monitoring of high condition streams with a focus on effects of reduced rainfall and forest management, addressing KPI1.

### Aims

- Address KPI1 of the 2014-2023 FMP by monitoring the condition of currently healthy streams in relation to reduced rainfall and forest management practices.
- Address KPI3 of the 2014-2023 FMP by determining responses of fauna of high value Warren region wetlands to changes in hydrology, water chemistry and fire over the last 10 to 20 years.
- Provide baseline data for some internationally significant wetlands.
- Use the above information to report on the current conservation significance of key departmental managed wetlands and their response and vulnerability to threats.

### Progress

- A manuscript comparing aquatic invertebrates sampled in 1995/96, 2003/04 and 2014/16 was progressed.
- The large collection of aquatic invertebrate specimens have been curated by volunteers for long-term storage.

### Management implications

- Re-surveying the Muir-Byenup System Ramsar site and other high value wetlands in the Warren region will provide the department with knowledge of how these wetlands and their fauna have responded to

threats (especially altered hydrology and water quality arising from land-use change and climate change) over the last 20 years. Analyses are showing that aquatic invertebrates in some Muir-Byenup wetlands are being significantly affected by acidification. In conjunction with results from the peat wetlands project (SP 2014-24), this project will assist the department with making decisions about protecting remaining high conservation value wetlands versus taking remedial action at those where condition is declining.

### Future directions

- Complete the paper comparing invertebrate communities present in the Muir-Byenup wetlands.



### Advancing the hydrological understanding of key Wheatbelt catchments and wetlands to inform adaptive management

SP 2015-001

J Rutherford

### Context

Changes in the hydrology of Toolibin Lake and the Lake Bryde catchments, due to land clearing, has resulted in these previously ephemeral freshwater wetlands developing a connection with deeper, saline groundwater and becoming degraded. A decline in average rainfall since the 1970s has seen a further decrease in wetland health as surface water flows and wetland hydroperiods decrease in quantity and quality. Robust management decisions require the main hydrological driver(s) of change to be identified and spatial and temporal fluxes (water and solutes) to be characterised. This project will significantly advance hydrological studies at Toolibin Lake and Lake Bryde by making full use of the data collection and analyses undertaken to date to produce practical tools for answering the key hydrological management questions.

### Aims

- Produce quantitative conceptual hydrogeological model(s) for Toolibin Lake and Lake Bryde.
- Produce a numerical groundwater model to assess the Toolibin Lake water balance and determine the effectiveness of groundwater pumping (individual pumps) in returning the lake to a perched status.
- Evaluate catchment water and salt hydrodynamics (groundwater and surface water contributions/fluxes) tested using numerical modeling under different climate regimes at Toolibin Lake.
- Investigate the links between key ecological parameters (e.g. tree and understorey health, bird breeding, richness of aquatic invertebrates) and hydrological status of Toolibin Lake.
- Produce risk assessment framework(s) to prioritise conservation actions and assess the transferability of research outcomes.

### Progress

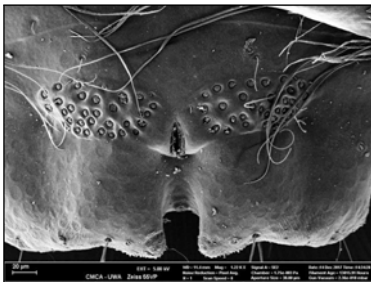
- A conceptual model of Toolibin Lake has been developed to explain how climate and engineering interventions have modified surface water and groundwater interactions over the past forty years.
- An extension of the study to include an assessment of the surface water inundation of Toolibin Lake in February 2017 has allowed the spatial variation in hydrological processes (e.g. recharge and discharge) to be mapped and quantified. This includes resolving where recently formed low salinity aquifers sustain *Melaleuca* sp. and *Casuarina obesa*, the threatened ecological community (TEC).
- Studying environmental tracers has provided further insight into the ages of the groundwater and salt stores in Wheatbelt aquifers.
- A three dimensional model to simulate hydrological processes has been constructed and is being used to predict areas where water management is more effective and hydrologically suited for revegetation by TEC species.

## Management implications

- The research methodology is transferable to other wetlands and is being tested in peat wetlands in the Muir-Byenup System Ramsar site (see SPP 2014-024).
- This study revised porosity and permeability of sediments and found rates of groundwater and solute movement were lower than previously predicted. This was supported by environmental tracer and numerical modelling results, the latter in preparation. This is an important finding that will help develop achievable hydrological management targets.
- Toolibin Lake and its local catchment now has a robust conceptual and numerical model that form the scientific basis for the refinement of management actions, which include the strategic placement of lake revegetation, the development of an optimised groundwater pumping program and an integrated platform for assessing the needs for current and future engineering works.

## Future directions

- Work with CyMod Systems in simulating hydrological processes outlined in the conceptual model under different climatic regimes.
- The combined results from the conceptual and numerical modelling will be used to develop a risk assessment framework for Toolibin Lake and its catchment.
- Present results from the conceptual and numerical model to the Wheatbelt Region and complete journal articles and DBCA science information sheets on Toolibin Lake hydrology.



## Taxonomy, zoogeography and conservation status of aquatic invertebrates

SP 2014-025

A Pinder, K Quinlan

## Context

Taxonomic knowledge underpins effective management of aquatic invertebrate biodiversity, including spatial patterning and trends over time in relation to threats. Over half of the species dealt with are not formally described, but they are consistently named across departmental projects through maintenance of a voucher specimen collection. As opportunities and skills allow, program staff undertake systematics studies (primarily species descriptions and genetic analyses), sometimes with specialist co-authors. This allows formal naming and description of Western Australian endemics that would not otherwise occur and allows species to be consistently identified by external research groups. Tools allowing consistent identification of aquatic invertebrates will also be produced.

## Aims

- Undertake aquatic invertebrate systematics to improve description of Western Australian aquatic invertebrate biodiversity and allow more consistent identification of specimens by departmental and external researchers.

## Progress

- A book chapter on Australian aquatic oligochaete was submitted.

## Management implications

- The description of new species and the production of taxonomic tools, will allow more routine and consistent identification of this group, including in environmental impact assessment.

## Future directions

- Undertake similar taxonomic work opportunistically and as required.



### Understanding peat wetland resilience: evaluating the impact of climate and landuse change on the hydrodynamics and hydrogeochemistry of peat wetlands in the Warren (Muir-Byenup) District

SP 2014-024

J Rutherford

## Context

Peat wetlands are relatively rare in Western Australia but constitute an important habitat for biodiversity where they occur, especially in the far south-west of the State, providing refugia from seasonal and long-term drying for a range of restricted flora and fauna. Some peat wetlands in the Muir-Byenup System Ramsar site wetland suite are threatened by acidification and some have already acidified as a result of declining groundwater levels. Drying is also making these organic wetlands more prone to catastrophic fires. The peat also stores a range of toxic metals and metalloids that are released to the environment as they dry. The major aim of this project is to undertake a risk assessment of fire susceptibility and release of acidity and other contaminants. The project will deliver a map of the distribution of at-risk peat wetlands, combined with recommendations for fire management and maintaining water balance.

## Aims

- Determine current hydrogeological and hydrochemical conditions of four representative peat wetlands, particularly water and chemical conditions and gradients.
- Map and quantify peat wetland carbon and acid stores.
- Identify and assess the transient behaviour of major threats to the health of the peat wetlands particularly the role of drying climate in changing water retention in peat sediments and the source and mobility of acidity and salinity.

## Progress

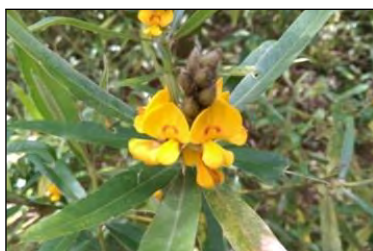
- Research was extended to study a peat wetland that has experienced partial acidification. Additional work carried out has involved sampling and analysing peat soil and water in the area releasing acid. Data loggers have also been installed to monitor groundwater levels and water quality in the four peat wetlands studied.
- Hydrological data confirms that wetland acidification takes place in response to changes in climate. Susceptible wetlands are those with peat substrates that have a limited connection with groundwater, and are sensitive to lower rainfall-runoff and increased evaporation.
- Initial geochemical monitoring data have been interpreted and reported. Results show all peat wetlands have high metal and metalloid concentrations and these analytes tend to be released and concentrate in-situ, when peat is subjected to longer periods of drying, via evaporation.

## Management implications

- All peat wetlands have the potential to become acidic as their high carbon content and low porosity and permeability encourages the storage of metals and metalloids. This study shows that the drying of peat in wetlands is taking place across all study sites, but areas producing higher acid fluxes are localised and have different hydrological controls. The development of management plans and priority actions therefore requires an understanding of both the magnitude of acid fluxes, and the hydrological processes that control the current and future extent of the acidification (e.g. lower rainfall-runoff, increased evaporation or reductions in groundwater discharge).

## Future directions

- Finalise hydrological and hydrogeochemical monitoring data collection for the four peat wetlands and acidified zone.
- Complete work on the three dimensional hydrogeological models so they can form the framework to assess the spatial variation in hydrological processes and acid stores and fluxes.
- Undertake geochemical and water balance modelling to verify results and identify wetlands where interventions are likely to be effective and the risk of peat fires reduced.
- Write a report, journal article and DCBA science information sheet that details the approach and application for management.
- Map and characterise peat wetlands in the Warren Region to better understand the likely distributions of threatened flora and fauna and risks of landscape threats (e.g. climate change, fire) to these systems.



## Restoring natural riparian vegetation systems along the Warren and Donnelly Rivers

SP 2013-004

M Byrne, T Hopley

### Context

Current practices of seed sourcing for revegetation projects focus on local seed, based on a premise of maximising adaptation to local conditions, but this may not be the most appropriate under changing climatic conditions. Identification of patterns of adaptive variation will enable more informed approaches to species selection and seed sourcing to maximise establishment and persistence of plants in revegetation programs.

This project will provide a climate change framework for revegetation of blackberry-decline sites on the Warren and Donnelly rivers by determining the scale of adaptation to climate along the river system and determining the best seed source strategies to maximise resilience to future changes in climate in the revegetated populations.

### Aims

- Develop a climate change framework for revegetation of riparian vegetation along the Warren and Donnelly rivers.
- Determine seed sourcing strategies that account for climate adaptation to enable resilient restoration of riparian vegetation along the Warren and Donnelly rivers.
- Test adaptation to climate through experimental plantings under operational conditions of establishment.

### Progress

- Analysis of genetic structure and association with climate variables showed differing patterns in the number and scale of signals of selection for *Astartea leptophylla* compared to *Callistachys lanceolata*. The species restricted to the riverbank, *A. leptophylla*, showed low signal of selection suggesting that environmental factors associated with microclimate in the riparian habitat and high gene flow may have greater influence than broader climate in this species. The more widespread *C. lanceolata* that has less connectivity and less gene flow showed stronger signals of selection associated with climate. A paper has been published in *Genes*.
- Analysis of genetic structure and association with climatic variables has identified signals of selection for *Taxandria linearifolia*. A manuscript is in preparation.

### Management implications

- Changing climates require a re-evaluation of appropriate seed sourcing strategies for revegetation and restoration of ecological function in degraded sites. Use of local seed will not provide adequate resilience to maintain ecological function under changing climates, and understanding of climate adaptation will provide a scientific basis to undertake best-practice restoration and facilitate establishment of biodiverse plantings that maximise ecological function for enhanced persistence and resilience.

- Current findings extend our understanding on the factors that influence selection across climate gradients, confirming that gene flow influences signatures of selection. These results also verify the need for management strategies that support genetic connectivity and, when needed, intervention to assist migration of genes to maximize the resilience of populations and species persistence in the face of changing climates.

### Future directions

- This project will be complete when a manuscript on genetic structure and signals of selection in *T. linearifolia* is published.



## Responses of terrestrial vertebrates to timber harvesting in the jarrah forest

SP 2012-038

A Wayne, C Ward, M Maxwell

### Context

Understanding the impacts of timber harvesting on the terrestrial vertebrates of the jarrah forest is necessary for biodiversity conservation and development of ecologically sustainable forest management.

### Aims

- Investigate the impacts of current silvicultural practices on jarrah forest ecosystems.
- Determine what factors contribute to observed impacts.
- Develop or modify silvicultural prescriptions to ensure the ecologically sustainable management of timber harvesting in the jarrah forest.

### Progress

- Spotlight monitoring using distance sampling methods on three standardised transects was maintained with six repeat surveys per transect per year. Ngwayir (western ringtail possum) populations in the greater Kingston area remain extremely low having declined to almost undetectable levels between 2001 and 2012. The early signs of a small recovery (2012 – 2018) of up to 7 percent of peak levels in 1998 have not been sustained. Ngwayir detection rates in 2020 so far, is <4 percent of pre-decline levels.
- A digital data capture platform developed for use on a tablet has been trialled and adopted by the project. It reduces data entry time while maintaining data quality in a secure way. The app is available for other spotlight programs to use.

### Management implications

- Identification of decline in the ngwayir numbers in the Upper Warren region (including greater Kingston area) contributed significantly to the recent elevation of its conservation status to critically endangered.
- Information on the impacts of timber harvesting on terrestrial vertebrates will lead to improved ecologically sustainable forest management practices and the conservation of biodiversity.
- Understanding the factors responsible for changes in populations of native mammals in the Upper Warren area provides critical context for informing management of fauna in areas subject to timber harvesting and other management activities.

### Future directions

- Data on the responses to timber harvesting of terrestrial vertebrates will be analysed and prepared for publication.





## Western Australian flora surveys

SP 2012-005

M Lyons, A Markey, S van Leeuwen, M Langley, M Collins, M Byrne

### Context

Flora surveys of targeted areas provide knowledge of vegetation pattern and structure for conservation management. These surveys are undertaken for a variety of purposes and for, or in collaboration with, a number of partner organisations. Current projects include:

- Floristic survey and vegetation mapping of the mound springs and surrounding vegetation communities of Walyarta Conservation Park (Mandora Marsh) in collaboration with the West Kimberley District.
- Flora and vegetation survey of Fitzroy Valley in collaboration with the West Kimberley District and traditional owners.
- Floristic survey of the Mound Springs of Dampier Peninsula and Carlton Hill Station in collaboration with the Kimberley Region and traditional owners.
- Floristic survey of Lake Carnegie wetland vegetation.

### Aims

- Undertake targeted surveys aimed at providing specific management advice, monitoring long term change in vegetation at specific sites or in specific communities, or to fill specific data gaps.

### Progress

- A vegetation map and interim report for the vegetation of Walyarta Conservation Park have been completed and provided to various stakeholders. The final full flora and vegetation report is in progress.
- The field program and species identifications have been completed, and the final stage of report preparation is underway, for a survey of selected land parcels in the Fitzroy Valley.
- A report chapter was written on the flora of Kimberley Region mound springs and the Nimalarragan wetland at Willie Creek north of Broome.
- Field surveys of gypsum plant communities of Western Australia have been completed in collaboration with Spanish researchers as part of the EU funded GYPWORLD project. Plant material of gypsophile and gypsocline taxa for nutrient and molecular analysis have been provided to these collaborators. Phylogenetic studies will focus on the genus *Frankenia*, a significant component of the State's gypsum flora with several taxa of conservation significance.
- Field work for a survey of the flora of Lake Carnegie wetlands and fringing landscapes has been undertaken, and plant samples have been processed in preparation for identifications and databasing.
- Data curation of Tutanning Nature Reserve Flora data has been undertaken with 22,058 records checked and edited against field sheets for inclusion in Data Catalogue and transfer to the relevant DBCA Regional office.
- AusPlots vegetation and soil survey methods for the Australian Rangelands have been published in *Frontiers in Ecology and Evolution*.
- A paper has been published in *Plant Methods* addressing plant identification and phylogenomics for 600 Pilbara species using genome skimming approaches. Samples have been sourced and prepared for another 400 species.
- Lodgement of plant specimen vouchers from the Kimberley Islands Biodiversity survey has been completed, with an additional 2,573 specimens submitted to the Western Australian Herbarium.

### Management implications

- A comprehensive DNA barcode library for Pilbara plants species will facilitate rapid plant identifications that will support traditional identification approaches while also clarifying the taxonomic status of many species and species complexes. This barcode library will also support the development of a proposed Pilbara

eflora and relax restrictions on field sampling time for plant specimens as fertile vouchers, particularly for ephemeral species, will no longer be essential to confirm identification.

- Kimberley mound springs surveys (Dampier Peninsula and Carlton Hill) will provide the locations of significant weed occurrences (date palm) and priority taxa to guide mound spring management. Documentation of the floristic values of the springs provides important context for assessing possible future impacts of any proposed groundwater abstraction projects.
- Walyarta Conservation Park (Mandora Marsh) vegetation survey and mapping will enable identification of vulnerable vegetation communities for monitoring, and is currently providing information for both a monitoring plan to determine the effectiveness of feral herbivore exclusion or removal and for interpreting hydrogeological findings.
- The Fitzroy Valley survey will provide vegetation site descriptions and updated floristic information for a region that has been relatively unsurveyed and is under consideration for inclusion in the reserve system.
- The Lake Carnegie flora survey will provide vegetation descriptions for assessment of the conservation status of Lake Carnegie, management planning and provide a baseline for monitoring.
- Phylogenetic studies in *Frankenia* will assist with the circumscription of taxa of conservation significance to underpin assessment of the impacts of gypsum mining proposals.
- Tutanning flora data and species traits data will be useful for determining species distribution, vegetation descriptions and ecological responses and should be useful to regional adaptive management projects.

### Future directions

- Complete a paper on Jurien coastal wetland flora.
- Analyse and continue to build genome library of Pilbara plant species.
- Finalise curation of Tutanning flora data records and voucher relevant collections.
- Complete plant identifications and report on Lake Carnegie flora.
- Complete reports on flora of Walyarta and Fitzroy Valley surveys.



### Long-term stand dynamics of regrowth forest in relation to site productivity and climate

SP 2011-020

L Mccaw, R Mazanec

### Context

This project provides information to underpin the management of karri and jarrah regrowth stands in the immature stage of development (25-120 years old). Regenerated stands have important values for future timber production, biodiversity conservation and as a store of terrestrial carbon. Immature karri stands that regenerated following timber harvesting and bushfire comprise more than 50,000 hectares and represent around one third of the area of karri forest managed by the department. Large parts of the jarrah forest are also comprised of predominantly even-aged regrowth. There are a number of well-designed experiments that investigate the dynamics of naturally regenerated and planted stands managed at a range of stand densities. These experiments span a range of site productivity and climatic gradients and have been measured repeatedly over several decades, providing important information to support and improve management practices.

This project addresses emerging issues for the next decade of forest management including climate change and declining groundwater levels, interactions with pests and pathogens, and increased recognition of the role of forests in maintaining global carbon cycles. The scope of this project has been broadened to include thinning response of even-aged jarrah stands, with all thinning experiments now covered by a single project plan.

### Aims

- Quantify the response of immature karri and jarrah stands to management practices that manipulate stand density at establishment or through intervention by thinning. Responses will be measured by tree and stand growth, tree health and other indicators as appropriate (e.g. leaf water potential, leaf area index).

## Progress

- The effects of thinning on growth and inter-tree competition in regrowth stands of jarrah and karri have been analysed using data from long-term experiments at Inglehope and Sutton forest blocks respectively. Four manuscripts are close to being ready for submission.
- Experimental infrastructure was re-established following second thinning of 1972 regrowth karri forest at Warren block.
- Information from long-term experimental studies has been collated for inclusion in a review of thinning practice in south-west forests.

## Management implications

- Thinning concentrates the growth potential of a site onto selected trees and provides forest managers with options to manage stands for particular structural characteristics that may be important for future yield of wood products, wildlife habitat or resilience to disturbance. Thinning is also an important tool for managing streamflow and groundwater levels in forested catchments in the face of a drying climate.
- Tree mortality associated with *Armillaria* root disease appears to reduce in older karri stands, and small gaps created by dead trees become less obvious as stands mature. Localised tree mortality can be regarded as a natural process and is likely to contribute to patchiness in the mature forest. However, the extent of tree mortality in silviculturally managed stands should be monitored to ensure that stand productivity and other forest values remain within acceptable ranges.

## Future directions

- Finalise and submit manuscripts analysing tree growth at Inglehope and Sutton thinning experiments.
- Review the findings from long-term thinning experiments to inform future management options for maintaining forest health and productivity in a drying climate, in preparation for the next forest management plan.



## Management of invertebrate pests in forests of south-west Western Australia

SP 2011-019

J Farr, A Wills

## Context

Within the history of forest and natural landscape management in Western Australia, many invertebrates are known to utilise forest biomass for their survival and in doing so impart some form of damage to leaves, shoot, roots, stems or branches. There are ten recognised invertebrate species with demonstrated significant impact on tree health, vitality and timber quality within our natural environment. Currently the most prevalent insect pests of concern in native forests are *Perthida glyphopa* (jarrah leafminer, JLM), *Phoracantha acanthocera* (bullseye borer, formerly known as *Tryphocaria acanthocera* BEB) and *Uraba lugens* (gumleaf skeletoniser, GLS). Both JLM and GLS have documented population outbreak periods, and BEB incidence appears to be responsive to drought stress and is likely to increase. However, Western Australian forests and woodlands also have a history of developing unexpected insect outbreaks with dramatic consequences for the ecosystem health and vitality. The decline in mean annual rainfall in south-west Western Australia since the 1970s and global climate model predictions of a warmer and drier environment mean conditions for invertebrate pests will alter significantly in the next decade as our environment shifts toward a new climatic regime. This project addresses both recognised and emerging/potential invertebrate forest pests, and is designed to augment forest health surveillance and management requirements by providing knowledge on the biological aspects of forest health threats from invertebrates in the south-west of Western Australia.

## Aims

- Investigate aspects of pest organism biology, host requirements, pathology and environmental conditions (including climatic conditions) that influence populations.
- Determine distribution of the invertebrate pests, including outbreak boundaries and advancing outbreak fronts, using aerial mapping, remote sensing and road surveys.
- Measure relative abundance of invertebrate pests, including quantitative population surveys and host/environmental impact studies where appropriate and/or possible.

## Progress

- Incidence of *Uraba lugens*, the gumleaf skeletonizer (GLS) was surveyed by visual inspection of established survey points in the Warren region. A report was prepared and distributed detailing the absence of outbreak populations this summer.
- A paper was published dealing with an historical *Cardiaspina jerramungae* outbreak using herbarium specimens, and the recurrence of rainfall conditions coincident with an outbreak in the 1980s in the Great Southern.
- Sites in the Southwest and Warren Regions were photographed to document the health of *Eucalyptus rudis* crowns and provide a baseline of information regarding the spread of decline symptoms into the Warren Region.

## Management implications

- Integration of GLS population and impact data from two major outbreak events indicates a strong relationship between GLS outbreak and periods of below-normal rainfall at seasonal or longer timescales. Further outbreaks are likely given present declining trends in rainfall.

## Future directions

- This project is complete.



## Western Australian wetland fauna surveys

SP 2011-018

A Pinder, K Quinlan, L Lewis, D Cale

## Context

Regional biological surveys provide analyses of biodiversity patterning for conservation planning at broader scales but sites in these projects are usually too sparse for use at a more local scale, such as individual reserves, catchments or wetland complexes. This project is designed to fill gaps within and between the regional surveys by providing aquatic invertebrate biodiversity data and analyses at finer scales. Past examples of such projects are surveys of wetlands in the Drummond, Warden and Bryde Natural Diversity Recovery Catchments, the Hutt River/Hutt Lagoon catchments and the mound springs near Three Springs. This project runs on an 'as-needed' basis.

## Aims

- Provide understanding of aquatic biodiversity patterning at the scale of individual wetlands to wetland complexes, catchments or regions to inform local conservation planning and as baselines for future monitoring.
- Provide better data on the distribution, ecological tolerances and conservation status of aquatic fauna species and communities.

## Progress

- Produced report on aquatic invertebrate communities from remote springs in the Great Sandy Desert, including Dragon Tree Soak threatened ecological community. One spring had elevated nutrient concentrations and associated water quality issues, probably from camel visitation.
- Processed aquatic invertebrate samples as a continuation of wetland survey work in the Goldfields.
- Produced report on temporal patterns in biodiversity and water quality at Lake Wheatfield and Goonapping Swamp.
- Sampled aquatic invertebrate abundance and composition at Lake McLarty for Peel-Harvey Catchment Council and completed identifications.
- Surveyed aquatic invertebrate communities of Little Darkin Swamp in the Darling Ranges.
- Undertook a reconnaissance trip to Lake Carnegie to gather preliminary information and followed this up with a survey of flora and fauna in the salt lake and associated wetlands.
- Survey and monitoring data was used to assess aquatic invertebrates for listing as priority species.

## Management implications

- Data on invertebrate communities and water quality of Great Sandy Desert springs provides a baseline for understanding values and for monitoring effectiveness of management such as feral animal control.
- Mining and pastoralism are ongoing threats to wetlands in the Goldfields Region and new knowledge of the biodiversity values of different types of wetlands will assist with environmental impact assessment and conservation status.
- The biological survey of Lake Carnegie and associated wetlands will contribute to a management plan and other conservation measures for this proposed addition to the conservation estate.
- Data on aquatic invertebrates and water quality provides a contemporary baseline for Lake McLarty and Little Darkin Swamp and indicate these wetlands are in good condition despite concerns about acidification at Lake McLarty.

## Future directions

- Publish a paper on invertebrate diversity in vegetated claypans of south-west Western Australia.
- Write a paper on the Lake Carnegie wetland survey including other Goldfields data.
- Write a paper on biodiversity patterning across Kimberley springs.
- Survey additional wetlands in the northern Wheatbelt for the brine shrimp *Parartemia extracta*.
- Further assess the conservation status of south-western Australian aquatic invertebrates.
- Write journal article on the influence of regional versus local habitat availability for Warden and Gore system waterbirds.



## Identification of seed collection zones for rehabilitation

SP 2006-008

M Byrne, H Nistelberger, S McArthur

## Context

The Conservation and Ecosystem Management Division of the department provides guidelines to the Forest Products Commission on seed collection zones for forest rehabilitation. Rehabilitation of sites through revegetation requires knowledge of the genetic adaptation of species to sites in order to manage in an ecologically sustainable fashion. This requires an understanding of the genetic structure and local adaptation of species.

## Aims

- Identify appropriate seed collection zones (provenances) for species being used for rehabilitation. Initial work is focused on species in the jarrah and karri forest where seed is used for rehabilitation after logging.

## Progress

- Analysis of genetic relationships among *Corymbia calophylla*, *C. haematoxylon* and *C. ficifolia* shows distinct genetic separation in the nuclear genome and shared cpDNA haplotypes, consistent with shared evolutionary history. A paper is in preparation.
- A paper has been submitted for publication in *Ecology and Evolution* with analyses of variation in microsatellite and cpDNA in 28 populations of *Banksia sessilis*. This has revealed two major genetic clades, one on the Darling Range and Plateau, and another on coastal limestone that exhibited higher genetic diversity and greater structure. The patterns of genetic diversity and phylogeographic structure suggest the ancestor to these clades originated in the northern coastal environment and diversified through the Darling Plateau during the mid-Pleistocene.

## Management implications

- Knowledge of genetic structure and local adaptation will enable identification of appropriate seed collection zones for rehabilitation of forest areas, in order to maintain the genetic integrity of the forest on a sustainable basis. Data from previous research on *Kennedia coccinea*, *Bossiaea ornata* and *Allocasuarina humilis* indicate that seed collected from the same landscape management unit as the area to be rehabilitated would be an acceptable seed-sourcing strategy. Alternatively, where seed is not readily available from the relevant landscape management unit then use of seed from nearby areas in adjacent landscape management units would also suffice. This information has been used to update seed collection zones for forest rehabilitation in the *Forest Management Plan 2014-2023*.

## Future directions

- Complete publication of genetic analysis of *Corymbia* species.



### **FORESTCHECK: Integrated site-based monitoring of the effects of timber harvesting and silviculture in the jarrah forest**

SP 2006-003

J Farr, V Tunsell, B Ward, A Wills, L Mccaw

## Context

FORESTCHECK is a long-term monitoring program and results will be used by forest managers to report against Montreal Process criteria and indicators for ecologically sustainable forest management. Initiated as a Ministerial Condition on the *Forest Management Plan 1994-2003*, FORESTCHECK has continued to be incorporated in the *Forest Management Plan 2014-2023* as a strategy for increasing knowledge on the maintenance of biodiversity and management effectiveness in Western Australian forests.

## Aims

- Quantify the effects of current timber harvesting and silvicultural practices in the jarrah forest (gap creation, shelterwood, post-harvest burning) on forest structural attributes, soil and foliar nutrients, soil compaction and the composition of the major biodiversity groups including: macrofungi, cryptogams, vascular plants, invertebrates, terrestrial vertebrates and birds.

## Progress

- Seven monitoring grids in the Jarrah Forest Sandy Basins ecosystem were re-measured for plant species composition, cover and structure. Camera surveys of vertebrate fauna activity were undertaken.
- Post-burn assessments were undertaken on grids at Plavins and Gobblecannup blocks burnt by prescribed fire. Six grids burnt by the Yourdamung bushfire in December 2019 were also visited to assess fire severity and restore fire-damaged infrastructure. Consumption of coarse woody debris was quantified at all burnt grids by re-measuring permanent transects.

- A paper reporting monthly patterns of understorey flowering activity over a two year period following fire was published in *Australian Forestry*. This paper utilised data collected following prescribed burning at four monitoring grids in Perth Hills District and following summer bushfire at six grids in Wellington District.
- A manuscript examining understorey flowering activity in relation to environmental conditions and the Noongar seasonal calendar is in preparation.
- A manuscript examining ground surface macroinvertebrate responses to silviculture and wildfire is in preparation.

### Management implications

- FORESTCHECK provides a systematic framework for evaluating the effects of current silvicultural practices across a range of forest types and provides a sound basis for adaptive management.
- Findings from the project continue to inform a variety of forest management policies and practices and have been incorporated in periodic revision of silvicultural guidance documents. Monitoring data have been used to verify predictive models for forest growth and species occurrence.
- The network of FORESTCHECK grids also provides a framework for monitoring responses to random disturbance events such as bushfires and extreme droughts, and for examining the impacts of a changing climate over the longer term.

### Future directions

- Report on findings from monitoring undertaken in Jarrah Forest South and Jarrah Forest Sandy Basins ecosystems and publish findings from the 10-year monitoring period.
- Explore the potential of genomic techniques for ecological monitoring, for example using the fire chronosequence of grids in Perth Hills District.



### Hydrological response to timber harvesting and associated silviculture in the intermediate rainfall zone of the northern jarrah forest

SP 2000-003

J Kinal, L Mccaw, G McGrath

### Context

This is a long-term experiment established in 1999 to address part of Ministerial Condition 12-3 attached to the *Forest Management Plan 1994-2003*. Ministerial Condition 12-3 states that the department shall monitor and report on the status and effectiveness of silvicultural measures in the intermediate rainfall zone (900-1,100 mm/yr) of the jarrah forest to protect water quality.

### Aims

- Investigate the hydrologic impacts of timber harvesting and associated silvicultural treatments in the intermediate rainfall zone of the jarrah forest in a changing hydroclimate.

### Progress

- Monitoring of groundwater levels, streamflow, stream salinity and stream turbidity continued in Yarragil 4L, 4X, 6C, and Wuraming catchments in the Swan Region.
- Data loggers in Yarragil 4L, 4X and 6C catchments to monitor rainfall, streamflow, stream salinity, and stream turbidity were updated to Unidata Neon loggers, enabling real-time data capture and access remotely via the internet.
- All timber products resulting from the second experimental thinning of Yarragil 4L catchment in 2019 were removed.

- The first phase of silviculture to increase the intensity and duration of the hydrological response following thinning of Yarragil 4L is underway. This involves felling non-commercial trees not marked for retention and poisoning the stumps.
- An operation to protect retained trees in Yarragil 4L from potential heat damage from subsequent fires is underway. This involves removing heavy timber debris from a buffer zone around trees.
- A paper giving an overview of the second thinning experiment in Yarragil 4L was published in *The Forester*.
- A paper examining the relative contribution to streamflow generation in jarrah forest streams has been submitted to *Hydrological Processes*.
- Groundwater bores were remeasured at Crowea, Iffley and Poole experimental catchments in the Warren Region. Sixteen bores remain in contact with the groundwater layer.

### Management implications

- Experimental catchments provide a unique long-term record of the hydrological response of the jarrah forest to climate change and forest management practices.
- Monitoring in these catchments contributes to reporting on KPI 10 for the *Forest Management Plan 2014-23* that relates to stream condition and groundwater level within fully forested catchments.
- Monitoring of experimental catchments helps inform the effects of silviculture treatments on water balance.
- Re-thinning of Yarragil 4L provides an opportunity to examine the effects of the silvicultural treatments on the groundwater and surface water hydrology, biodiversity, and vegetation structure and composition of the catchment.

### Future directions

- Continue monitoring of groundwater levels, streamflow and water quality in the Yarragil catchments.
- Use isotope methods to examine shifts in water use by plants resulting from thinning.
- Synthesise historical fine scale changes in stream hydrological responses and biogeochemistry.
- Apply second phase of silviculture in Yarragil 4L and remeasure post-thinning stand density.



### Genetic analysis for the development of vegetation services and sustainable environmental management

SP 1998-007

M Byrne, S van Leeuwen, R Binks, M Millar, B MacDonald, S McArthur

### Context

Understanding the genetic structure and function of plants is important for their effective utilisation for revegetation, mine-site rehabilitation and provision of ecosystem services, such as hydrological balance, pollination and habitat connectivity.

### Aims

- Provide genetic information for the conservation and utilisation of plant species for revegetation and rehabilitation. Current work aims to identify seed collection zones for species used in rehabilitation of mine sites in the Pilbara.

### Progress

- Analysis of tree species, *Corymbia hamersleyana* and *Acacia pruinocarpa*, showed extensive gene flow across all populations in the Pilbara indicating high pollen and seed dispersal, possibly by water movements during cyclones. A paper has been submitted to *Genes*.
- Analysis of two small acacias shrubs with patchy distributions, *Acacia hilliana* and *A. spondylophylla*, show genetic differentiation among populations indicating some restrictions to gene flow in contrast to the widespread gene flow in the tree species. A manuscript is in preparation.



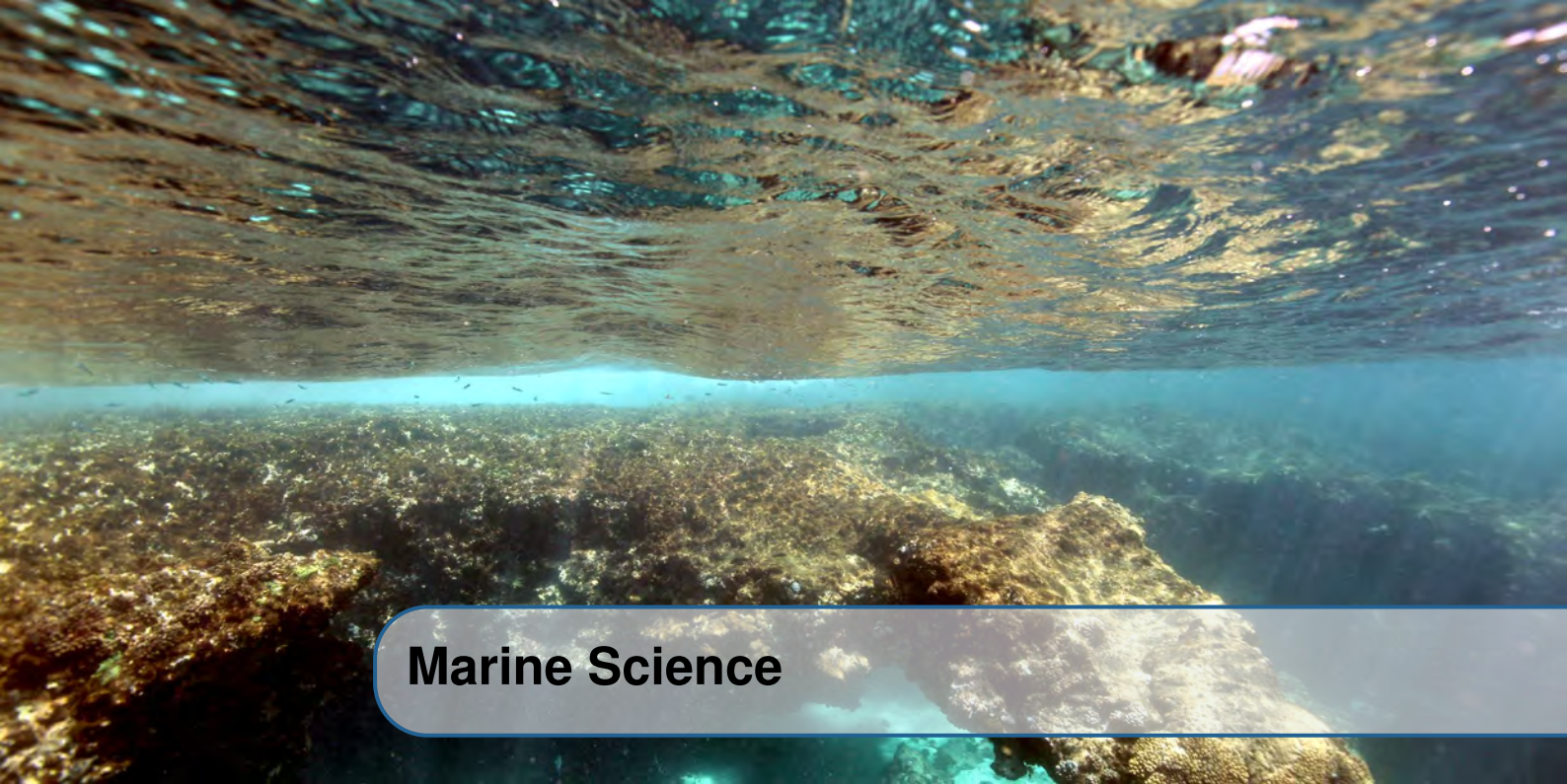
- Naturalised populations of *Acacia saligna* in Tigray, Ethiopia, have been sampled and genotyped with nuclear microsatellite markers. Genetic diversity is moderate and genetic divergence among populations is limited. The majority of Tigrinian individuals were assigned to the 'lindleyi' and more specifically the north-western 'lindleyi' genetic entity of the *A. saligna* species complex. A paper on diversity, divergence and origin of Tigrinian *A. saligna* is in press in *Tree Genetics and Genomes*.

### Management implications

- Pilbara seed collection zones - Moderate levels of genetic diversity and lack of differentiation within *C. hamersleyana* and *Acacia pruinocarpa* imply that seed resources for land rehabilitation and mine site revegetation programs for these species can be selected from a wide distributional range within the Pilbara. Low levels of differentiation across the ranges of *P. labicheoides* and *I. monophylla* allow for multiple, broad seed collection zones, while high genetic differentiation within the more restricted distributions of *A. hilliana*, *A. spondylophylla* and *M. viminalis* require more limited seed collection zones.
- Introductions of *A. saligna* present in Tigray provide a good basis for seed production, biomass for particle wood production, fuelwood and poles, whilst minimising invasiveness more prevalent in other subspecies of the species complex. There is opportunity to increase genetic diversity present in the informal subsp. 'lindleyi' in Tigray.

### Future directions

- Finalise papers reporting the genetic results for Pilbara species *Indigofera monophylla*, *Petalostylis labicheoides*, *Mirbelia viminalis* and *Senna glutinosa* subsp. *glutinosa*.
- Write a synthesis paper to summarise the broad genetic patterns in the eight Pilbara species, with a focus on seed collection zones for mining restoration.



## Marine Science

**Program Leader: Alan Kendrick** The broad goal of the Marine Science Program is to ensure the department's marine biodiversity conservation and management programs are based on best practice science. Specifically, the program promotes and undertakes marine research and monitoring to improve the scientific basis for the conservation and management of Western Australia's state-wide system of marine protected areas, threatened marine fauna and marine biodiversity generally. The program also coordinates and manages external marine research programs, such as the current investigation into the bio-physical, social and cultural values of the Kimberley that is undertaken as part of the Western Australian Marine Science Institution (WAMSI). The research and monitoring programs undertaken by the Marine Science Program are based around the research and monitoring strategies identified in protected area management plans and threatened species recovery/management plans, ensuring that all activities are clearly linked to departmental priorities and programs.



### Understanding the key ecosystem services provided by the seagrass meadows of Western Australia

SP 2018-136

S Strydom, S Wilson, B French, A Kendrick, K Murray, T Holmes, B Huntley

#### Context

Seagrasses are foundation species that support important ecosystem services and processes worldwide. Seagrass meadows are declining globally and anthropogenic related pressures such as terrestrial run-off, anchor damage and dredging are threatening the ecological, economic and social services that seagrass meadows provide. Some of the largest and most diverse seagrass meadows in the world occur in Western Australia and these support many commercially, recreationally and culturally important fauna. As the condition of seagrass meadows respond readily to pressures, they are used as indicators for the overall effectiveness of management across marine reserves managed by DBCA. Across-region comparisons and thorough temporal assessments of seagrass condition will provide a broader appreciation of seagrass health among the state's network of marine reserves. Furthermore, a greater understanding of how climate change related pressures (i.e. increased seawater temperature and extreme events) impact seagrass meadows and the ecosystem services they provide is needed. This is particularly the case in vulnerable regions like Shark Bay, where the full extent of seagrass loss since the 2010/11 marine heatwave in Western Australia's largest World Heritage Area was until recently not well understood.

## Aims

- Describe seagrass distribution and condition over time across the sub-tropical/temperate WA marine reserves.
- Establish appropriate methods for surveying and monitoring faunal communities in seagrass meadows.
- Assess faunal communities in different types of seagrass meadows across the seascape to inform how key ecosystem services are affected by pressures that impact seagrass condition.

## Progress

- Habitat mapping in Shark Bay (before and after 2011 marine heatwave) was undertaken and quantified the largest loss of seagrass globally. The extent of seagrass loss differed among regions of the Shark Bay World Heritage Area that were exposed to varying levels of heat stress. These findings were published in *Global Change Biology*.
- A comparison of five methods often used to assess fish assemblages in seagrass showed that trawling and stationary video techniques provided a sampling combination that best measured fish diversity and abundance. A manuscript describing this study has been submitted to *Ecological Indicators*.
- In order to assess fine-scale changes in seagrass meadow composition over time, a series of fragmentation metrics were calculated for seagrass meadows around Monkey Mia in Shark Bay Marine Park. Initial results suggest an increase in sparse seagrass and increased patchiness of meadows.

## Management implications

- Seagrasses are a key performance indicator for several marine reserves. Understanding natural variability in seagrass condition over time can be used to detect any abrupt or gradual changes outside of normal environmental conditions, particularly when links between seagrass condition and environmental pressures have been quantified.
- The habitat maps of Shark Bay provide seagrass distribution maps, estimates of temporal and spatial rates of change, and digital habitat databases that can be used as quick reference guides on seagrass meadow condition by researchers and managers across the entire World Heritage Area. This work may help to identify resilient areas and sea surface temperature metrics for predicting the effects of heat stress on seagrass.
- A sound understanding of seagrass fish communities, based on robust methods, provides a basis for their successful environmental management and conservation. We now know which methods are most appropriate for sampling fish communities within seagrass habitat, and which have the greatest power to detect change.

## Future directions

- Quantitatively assess trends in seagrass condition against key environmental predictors to determine which predictors have the ability to explain variation in seagrass condition over time.
- Assess the effect of different net mesh on fish samples collected using trawls in seagrass.
- Quantify fish assemblages among fragmented and non-fragmented meadows in Shark Bay and collect ground-truthing images to create a habitat map of seagrass extent for 2020.



### Long-term monitoring in the area of the proposed Dampier Archipelago marine reserves

SP 2015-015

M Moustaka, T Holmes, S Wilson, A Kendrick, K Murray

## Context

The Pluto LNG Project Offset D program includes the requirement to establish long-term monitoring reference sites in the proposed Dampier Archipelago marine reserves in accordance with the indicative management plan for the area. This task will require a prioritisation of ecological assets, the establishment of long-term monitoring

sites to assess spatial and temporal distribution of key assets, and the provision of quantitative evidence on the status of these assets. This work will also help develop best practice monitoring techniques for assets and pressures where knowledge is lacking, and provide valuable information for marine planning and conservation initiatives.

### Aims

- Develop and implement a monitoring, evaluation and reporting program of key biodiversity asset condition and their major pressures at key sites in the area of the proposed Dampier Archipelago marine reserves.

### Progress

- A draft of the ecological monitoring report for the Dampier Archipelago has been compiled.
- A tropical seagrass article was published in *Landscape*.
- A co-authored manuscript on coral recruitment patterns is in preparation.
- An EcoPic short image-based piece has been accepted for publication in *Frontiers in Ecology and the Environment*.
- One field trip to monitor seagrass, macroalgae, and water quality was undertaken.
- One field trip to capture remotely piloted aircraft (RPA) imagery of mangroves to develop monitoring products was undertaken.
- Fit-to-Park documents and standard operating procedures for ecological assets have been finalised.
- Tropical macroalgae monitoring methodology was developed.
- R scripts were developed to expedite data analysis and reporting for ecological assets.

### Management implications

- An established monitoring program will inform managers of trends in asset condition and associated pressures that will facilitate long-term adaptive management for the proposed reserves, and promote environmental understanding for a range of stakeholders and the community. The latest field trips conducted will add a third data point to the seagrass dataset and a second data point to the macroalgae dataset, further adding to the available baseline data for the region.
- Ground-truthing mangrove imagery collected by RPA will facilitate the use of higher resolution remotely-sensed imagery products available through new technology.
- New marine monitoring indicators and methods for macroalgae will provide a sound basis for assessing the condition of these ecological values in the Dampier Archipelago.

### Future directions

- Publish a co-authored manuscript on coral recruitment patterns in the Dampier Archipelago.
- Finalise the ecological monitoring report for the Dampier Archipelago.



## Habitat use, distribution and abundance of coastal dolphin species in the Pilbara

SP 2014-021

K Waples, H Raudino

### Context

Australian snubfin (*Orcaella heinsohni*) and Australian humpback (*Sousa sahulensis*) dolphins inhabit Australia's north-western coastal waters, but little is known about the population sizes, distribution and residency patterns of these species. Current knowledge of these dolphin species in the Pilbara is poor and is limited to a dedicated study of humpback dolphins in Ningaloo Marine Park and Exmouth Gulf, and opportunistic surveys and anecdotal sightings throughout the region. Although the presence of several coastal dolphin species is expected in

nearshore Pilbara waters (humpback, snubfin and bottlenose dolphins), very little is currently known of their residency and habitat use patterns.

Human pressures on these species are increasing in the Pilbara through activities associated with expansion of the resources sector, including oil and gas exploration and production, coastal infrastructure development and shipping. While this is a key factor that proponents are required to address to secure State and Commonwealth environmental approvals, impact assessments for these species are complicated by the lack of best practice protocols and standards for survey design and data collection, which limits the comparison of different studies and study sites. This project will provide a better understanding of these species and their spatial and temporal use of Pilbara coastal waters and lead to greater certainty in assessing and managing impacts that relate to industrial developments. This project was designed to meet this priority need under the Wheatstone Offset C program.

### Aims

- Determine habitat use, distribution, abundance, residency, and movement patterns of dolphins in coastal Pilbara waters.
- Identify the characteristics of habitats used by coastal dolphins, such as water depth, benthic substrate, and a range of environmental variables.

### Progress

- A paper was published on alternative genetic sampling techniques using a drone in the journal *Ecosphere*.
- A paper on minimum image resolution needed to differentiate between small coastal dolphin species from aerial survey has been submitted to a special issue of *Mammalian Biology*.
- Data collected during the 2019 field trip to Dampier Archipelago was processed and incorporated into the DoIFIN database for ongoing analyses.
- Data has been formatted and is being analysed using density surface modelling to better understand abundance estimation of coastal dolphins at a regional scale in the Pilbara.

### Management implications

- This research will provide a baseline understanding of dolphin habitat use in the Pilbara region, which will inform the assessment of environmental impacts relating to future coastal developments, and will assist to determine the conservation status of coastal dolphin species in Pilbara waters.
- The research will establish baseline data and long-term monitoring protocols for coastal dolphin species in State waters.

### Future directions

- Produce an abundance estimate of coastal dolphins in the Pilbara from aerial survey data.
- Complete assessment of a trial that involved the use of cameras during aerial survey.
- Undertake a boat based dolphin survey in the Montebello Islands Marine Park.



### Distribution and abundance estimate of Australian snubfin dolphins at a key site in the Kimberley region, Western Australia

SP 2014-018

K Waples, H Raudino

### Context

The current lack of knowledge of the Australian snubfin dolphin (*Orcaella heinsohni*) meant that its conservation status could not be properly assessed in 2011 due to insufficient information on population dynamics and distribution. This species is known from tropical coastal waters of Australia and New Guinea, but tend to be shy, evasive and difficult to study. Although they range southwards to the Pilbara region of Western Australia, there

has been little local based research on this species and much of this remains unpublished. This project will compile existing data on snubfin dolphins across the Kimberley to gain a better understanding of their habitat use and distribution. The collation of data into a single database will also facilitate the study of population structure and demographics based on recognised individual animals.

### Aims

- Provide a quantitative abundance estimate of snubfin dolphins for Roebuck Bay in Western Australia that will be used as a baseline for this population and will also enable comparison with abundance estimates of the species from sites at Cleveland Bay (Qld) and Port Essington (NT).
- Compare methods for abundance estimation (mark-recapture versus distance sampling) and the suitability of these methods for abundance estimation of this species.
- Map the extent of occurrence and area of occupancy of snubfin dolphins in the Kimberley by combining traditional knowledge and dolphin sightings from Indigenous sea rangers and scientific survey sightings.
- Refine and populate a purpose built and standardised database that will support long term data collection and curation in Western Australia and facilitate data-sharing between jurisdictions.

### Progress

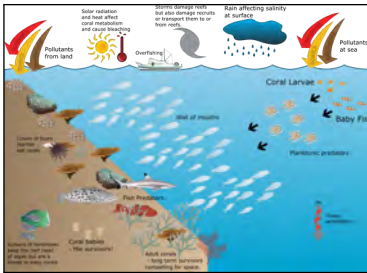
- A manuscript on broadscale distribution of snubfin dolphins across the Kimberley region using a range of data sources, including surveys with Indigenous partners is in preparation for a special issue of *Frontiers in Marine Science*.
- A vessel-based dolphin survey was undertaken in the Prince Regent River by DBCA staff and Dambimangari joint managers. Traditional owner elders were also taken on Country during the survey. A survey report and infographics have been provided to the joint managers.
- A *Landscape* article is being prepared on the snubfin census results in Yawuru Nagulagun/Roebuck Bay Marine Park in partnership with Nyamba Buru Yawuru and DBCA regional staff.

### Management implications

- Collation of scientific and traditional knowledge of a poorly understood marine mammal species of high conservation value means managers now have baseline knowledge of the abundance of snubfin dolphins in the Yawuru Nagulagun/Roebuck Bay Marine Park.
- Establishment of a database for all dolphin research and monitoring where survey and photo-identification data is collected ensures that standardised data is available for assessing population abundance and distribution. It also provides the capacity to develop sighting histories for individual animals, thus providing a better understanding of population demographics and life history. This database can also be used for information sharing across jurisdictions and between research organisations.
- The broad-scale collation of information and modelling has provided relevant information on area of occupancy and extent of occurrence that can be used to more accurately assess the conservation status of snubfin dolphins.
- The research has enabled partnerships to be established with Indigenous sea ranger groups to develop survey methodologies, data storage and reporting structures that are consistent with Healthy Country and reserve management plans.
- The Dolphin Watch app and Finbook photo-identification guide will support ongoing monitoring of the snubfin dolphin population in Roebuck Bay and will be used to address the key performance indicators related to maintaining abundance and diversity of these dolphin species in the Yawuru Nagulagun/Roebuck Bay Marine Park.

### Future directions

- Publish work on cross-cultural knowledge of the distribution of snubfin dolphins in the Kimberley to include species distribution modelling.
- Undertake a second snubfin dolphin census in Yawuru Nagulagun/Roebuck Bay Marine Park.



## Improving the understanding of West Pilbara marine habitats and associated taxa: their connectivity and recovery potential following natural and human induced disturbance

SP 2014-004

R Evans, S Wilson, R Douglas, B MacDonald, K Murray, G Pitt

### Context

The focus of work for Wheatstone Development Offset Project B will be to add to the understanding of west Pilbara marine habitats (including coral and seagrass communities) and associated taxa, including their level of connectivity and their recovery potential should they be impacted by natural and human induced disturbance. This research aims to build on existing knowledge and integrate with current and proposed connectivity projects on habitat-forming taxa and associated taxa in the tropical north-west of Australia. Broad-scale connectivity studies of flora and fauna within and between the offshore islands of the north-west continental shelf have shown varying levels of connectivity. Previous studies have also shown limited connectivity between inshore and offshore marine communities but there have been no studies looking at connectivity and recovery potential between locations within the Pilbara region, and their connections with the broader inshore locations of Ningaloo to the south-west, and the Kimberley to the north-east.

### Aims

- Determine levels of population connectivity and assess the extent and spatial scales of local adaptation.
- Correlate genetic parameters with modelling of environmental variables to determine factors that have a significant influence on connectivity.
- Investigate coral demographics and recruitment to understand how the environment influences the corals in the Pilbara.

### Progress

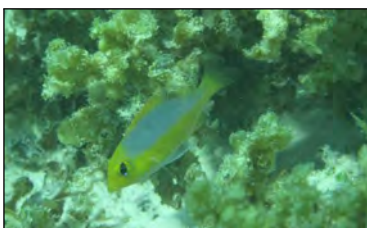
- A manuscript on coral recovery after multiple bleaching events in the Pilbara was published in the *Journal of Environmental Management*.
- A manuscript on coral core records of thermal acclimatisation and stress impacts during recent marine heat wave events, was published in the journal *Paleoceanography and Paleoclimatology*.

### Management implications

- Management should focus on improving or maintaining local water quality to increase the likelihood of coral recovery under climate stress. Further, in turbid environments, juvenile coral density predicts early coral recovery better than recruits on tiles and may be a more cost-effective technique for monitoring recovery potential.
- Coral core geochemical records provide unique perspectives of the variable impacts of marine heatwave events on coral reef environments. These coral cores provide historic context to coral reef impacts, which enable forecasting based on future climate change.

### Future directions

- Complete and submit manuscripts on coral and seagrass connectivity.



## The influence of macroalgal fields on coral reef fish

SP 2013-006

S Wilson, T Holmes, K Murray

## Context

Macroalgae are a prominent component of tropical benthic communities along the north-west coast of Australia. Within the Ningaloo Reef lagoon, large fields of macroalgae are a distinct feature of the marine park, covering approximately 2,000 hectares. These macroalgal fields are important habitat for fish targeted by recreational fishers and are a focal area for boating activity within the park. Moreover, large seasonal shifts in algal biomass on these and other tropical reefs suggest macroalgae play an important role in nutrient fluxes in Ningaloo and similar systems. Recent work at Ningaloo has quantitatively assessed seasonal variation in biomass and diversity of macroalgal communities. This project will build on the information gained from these initial studies to improve understanding of how macroalgae are distributed across the Ningaloo lagoon and better define the role of macroalgal fields as habitat for fish recruits and adults.

## Aims

- Quantify spatial variance in macroalgal fields at Ningaloo Marine Park and determine the relative importance of physical and biological drivers of algal abundance and diversity.
- Identify attributes of macroalgal fields favoured by juvenile fish and examine the relative importance of habitat quality and predation on juvenile abundance.
- Assess the influence of juvenile fish on replenishment and future adult abundance.

## Progress

- A review on fish assemblages in tropical macroalgae fields was published in *Fish and Fisheries*. The review, based on surveys from 23 locations in 11 countries, identified 627 fish species in macroalgal fields. Approximately a third of these species were predominantly found in macroalgal habitat as adults or juveniles. The abundance of fish in macroalgal habitats is often highest during the juvenile stage, providing further evidence that macroalgal habitats are important nurseries. Whilst some species are clearly macroalgal specialists, the majority of the fish species observed in macroalgal habitats were also seen in nearby coral or seagrass habitats, indicating that fish move across habitats to forage, reproduce or when they develop from juveniles to adults. While many macroalgal-associated species are of minor commercial value, their local importance for food and livelihood security can be substantial.

## Management implications

- Meta analyses of studies from around the world demonstrate that many fish species inhabit tropical macroalgal meadows during some part of their life and that these meadows are an important component of the tropical seascape.
- Tropical macroalgal habitats are important nurseries for fish of ecological and fisheries importance in Ningaloo Marine Park. Canopy forming macroalgal fields are therefore habitat of high conservation value that should be considered for protection when planning marine reserves.

## Future directions

- Undertake a follow-up study from the meta-analysis combining information collected on the distribution of fish and small-scale tropical fisheries to estimate the contribution of macroalgal habitats to fisheries.
- The spatial and temporal dynamics of canopy forming macroalgae at Ningaloo and how this is influenced by environmental disturbance will be examined.
- Undertake data analyses to understand links between juvenile and adult fish abundance.



## Understanding movements and identifying important habitats of sea turtles in Western Australia

SP 2013-002

S Whiting, T Tucker, S Fossette-Halot



## Context

This project uses satellite telemetry to track turtles that are released to the wild with minimal and extensive rehabilitation. In addition, turtles are tracked to identify connectivity between different habitats in their life stages. Commonly, turtles are tracked from nesting beaches to identify interesting habitat, migration routes and resident foraging grounds. The tracking results identify the geographic range and preferred habitats and provide insight into the viability and survivorship of healthy and rehabilitated turtles in the wild. The identification of preferred habitat allows pressures to be identified and prioritised for different size classes. As tracking results will be broadcast live on the internet (updated daily via [www.seaturtle.org](http://www.seaturtle.org)) there is a direct link between the department's science activities and the community. The genetic information (derived from samples collected routinely across a range of projects) will provide another layer of information that helps to describe the spatial range of sea turtles in Western Australia.

## Aims

- Determine the distribution and movement of sea turtles and investigate how components of sea turtle biology (including genetics) influence turtle distribution (including preferred sites), movement and foraging ranges.
- Investigate how environmental drivers, such as oceanographic factors, influence turtle distribution (including preferred sites), movement and foraging ranges.
- Investigate the viability and survivorship of rehabilitated turtles.
- Investigate connectivity of turtles between habitats across their life stages (commonly between nesting beaches and foraging grounds).

## Progress

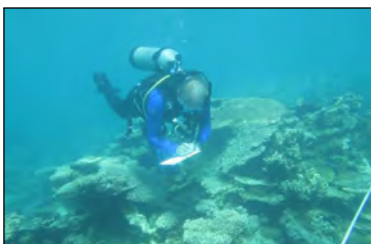
- Transmitters were deployed on flatback turtles at key areas, including Roebuck Bay feeding grounds.
- Transmitters were deployed on green and loggerhead turtles at the Muiron Islands and Ningaloo Coast, in collaboration with Woodside Energy, to understand inter-nesting behaviour and identify migratory paths and foraging areas.
- Movements of tracked turtles were displayed in real time on [www.seaturtle.org](http://www.seaturtle.org).
- Analysis of green and loggerhead turtle movements was finalised and a report completed.

## Management implications

- The identification of inter-nesting areas for both species informs the boundaries of Biologically Important Areas (BIA) as used by the Commonwealth in the *Recovery Plan for Marine Turtles in Australia*. Previously, BIAs for this life stage were only estimated for WA. This project provides some of the first quantifiable evidence to develop BIA's for migratory corridors and resident feeding areas for these species.
- Tracking flatback turtles in Roebuck Bay has provided cutting edge information to understand critical habitat and diet to assist management of the marine park.
- This project is conducted in partnership with Indigenous groups and knowledge is shared back to communities. Information is directly used by Western Australian marine park planning, in development assessment advice, and to update information for the *Recovery Plan for Marine Turtles in Australia*.

## Future directions

- Test and trial better attachment techniques for flatback turtles.
- Continue studies of flatback turtles in key foraging areas.
- Analyse and publish turtle tracking data.



## Marine monitoring program

SP 2012-008

T Holmes, C Ross, W Robbins, S Strydom, E D'Cruz, B French, M Moustaka, A Kendrick, K Murray, S Wilson, E Lester, J Goetze

## Context

A state-wide system of marine protected areas is being implemented and established in Western Australia as part of Australia's National Representative System of Marine Protected Areas. Long-term monitoring of the condition of ecological values and the pressures acting on them is seen as an integral aspect of adaptive management. The department's marine monitoring program is a state-wide, long-term, marine monitoring, evaluation and reporting program that is designed to increase the efficiency and effectiveness of marine reserve and threatened marine fauna conservation and management across Western Australia.

## Aims

- Implement a long-term monitoring program of key ecological values, and the pressures acting on them, in Western Australia's marine parks and reserves.
- Develop and implement a long-term monitoring program of threatened/protected marine fauna, and the pressures acting on them in State waters.
- Report results and findings of the monitoring program to departmental managers, joint management partners, public, peers and other key stakeholders to facilitate effective management and conservation of Western Australia's marine values.
- Continually evaluate and review monitoring and reporting programs to ensure that best practice science is adopted and that communication methods are appropriate for the intended target audiences.

## Progress

- Updated monitoring data was collected by DBCA or collated from direct collaborators for fish, coral, seagrass, macroalgae, mangroves, macro-invertebrates, little penguins, shorebirds, intertidal invertebrates, dolphins and water quality during fieldwork conducted across 15 marine reserves from Walpole and Nornalup Inlets Marine Park in the south to North Kimberley Marine Park in the north.
- Updated results and findings from the monitoring program were communicated to Marine Park Coordinators and Regional Managers via the annual Marine Park Performance Assessment process, written advice, and opportunistic presentations. This information included more detailed management implications and data interpretation for the Ningaloo, Shark Bay and Jurien Bay marine parks.
- Four scientific papers incorporating departmental monitoring data were published in the journals *Global Change Biology*, *Methods in Ecology and Evolution*, *Biological Conservation* and *Journal of Experimental Marine Biology and Ecology*.
- Significant scientific advice was provided as a part of the ongoing planning process for a marine park in the Buccaneer Archipelago, the management plan review of the Marmion Marine Park, Subsea 7 development application, the alignment of external research agency priorities (Minderoo Foundation, Mars Foundation) and externally contracted reports relating to shorebirds and intertidal invertebrate communities in the Eighty Mile and Yawuru Nagulagun marine parks.
- Data cleaning and analysis processes for fish, corals, seagrass and seawater temperature have been semi-automated through R-coding.

## Management implications

- The long-term marine monitoring program provides data that informs the evidence-based adaptive management of Western Australia's marine parks and reserves and threatened and specially protected marine fauna.
- Monitoring data is collected on key ecological values, and the pressures acting on those values to guide management responses. This performance assessment and adaptive management framework allows conservation managers to respond appropriately to changes as they become apparent, and to refine approaches to managing ecological values based on rigorous scientific evidence collected as a part of a strategic state-wide framework.

## Future directions

- Finalise and publish supporting documentation that describes the aims and structure of the marine monitoring program, including rationale for the selection of monitoring indicators and methods for key ecological values.
- Finalise and publish four ecological monitoring reports.

- Continue the implementation and periodic review of ecological value monitoring across the marine reserve system, including at the current approach to large-scale seawater temperature monitoring and the continued rollout of programs in recently created and proposed reserves in Western Australia's Kimberley region.
- Begin the process of periodic re-prioritisation of monitoring in the Kimberley marine reserves in collaboration with regional staff and joint managers .
- Continue to provide evidence-based knowledge of the condition of key ecological values and the pressures acting on them to inform and assist the delivery of adaptive management.
- Continue to provide the scientific knowledge for the marine parks and reserves reporting process.



## North West Shelf Flatback Turtle Conservation Program

CF 2011-118

S Whiting, S Fossette-Halot, T Tucker

### Context

The Northwest Shelf Flatback Turtle Conservation Program (NWSFTCP) is one of four environmental additional undertakings for the Gorgon Gas project at Barrow Island. The purpose of the program is to increase the conservation and protection of the Northwest Shelf flatback turtle population through: surveying, monitoring and research; reducing interference to key breeding and feeding locations; and establishing information and education programs. The Marine Science Program coordinates the planning and implementation of works required for the NWSFTCP in addition to coordinating general research and monitoring of marine turtles in Western Australia. The NWSFTCP has a range of governance arrangements that include an advisory committee and a scientific panel.

### Aims

- Implement the scientific management and communication strategies of the NWSFTCP Strategic Plan.

### Progress

- Studies on the foraging stage of flatback turtles continued at Roebuck Bay and included tracking turtles using satellite technology and using dive depth instruments and turtle mounted cameras.
- Foxes were culled for the second year at a major Pilbara flatback turtle rookery on Mundabullangana Station.
- National Light Pollution Guidelines were co-produced with the Department of Agriculture, Water and the Environment to help reduce light pollution impacts on marine turtles.
- Monitoring of nesting turtles was continued at two major rookeries and several intermediate sized rookeries.

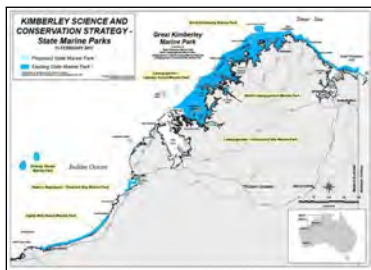
### Management implications

- The identification of resident flatback turtles in Roebuck Bay has allowed determination of their seasonal distribution and population structure in terms of sex ratios and maturity structure. This has allowed joint managers (DBCA and Yawuru Aboriginal Corporation) to consider this information in terms overlap of flatback turtles with marine park and port management areas, and with stakeholder use such as pearling, shipping and recreational boating. Turtle-borne cameras and satellite tracking data have provided information on habitat use which has helped managers redefine requirements for habitat mapping.
- This program continues to cull foxes at Mundabullangana Station to assist in protecting flatback turtles.
- A broad-scale aerial survey of nesting beaches across the Pilbara has identified all nesting habitat and defined relative nesting abundance across these areas. This information will be used to estimate the relative proportion of nesting that is potentially impacted by industrial developments and specifically, will assist the NWSFTCP to assess the potential impact from the Gorgon Gas Project to the North West Shelf flatback turtle genetic stock.

- Long term natural resource management benefits from community engagement through local partnerships. The inclusion of Indigenous groups (such as Yawuru Aboriginal Corporation and Ngarluma Aboriginal Corporation) as partners has enhanced the long-term benefits of the program by providing: a cultural perspective and relevance to the work; positive communication of the program throughout the communities; stability in governance and advice pathways; and additional conduits for information transfer to Joint Management bodies.

### Future directions

- Undertake hydro-dynamic modelling to predict areas and habitats most likely to support the presence of post-hatchling and neonate turtles.
- Undertake ageing studies using innovative techniques such as stable isotope and genetics analyses.
- Continue to monitor key flatback nesting beaches including Delambre and Thevenard islands, Port Hedland, Eco Beach and Cape Domett.
- Quantify the impacts of artificial light, climate change and feral animals on flatback turtles through student projects.
- Build and maintain Indigenous partnerships, engagement and employment through local opportunities and training.



### WAMSI 2: Kimberley Marine Research Program

CF 2011-117

K Waples

### Context

The Kimberley Marine Research Program (KMRP) represents a program of marine research to support the management of the Great Kimberley Marine Park (which includes State marine parks at Camden Sound, Horizontal Falls, North Kimberley, Roebuck Bay and Eighty Mile Beach) and the coastal waters outside of these marine parks. The KMRP was developed and implemented through the Western Australian Marine Science Institution (WAMSI), with DBCA as lead agency responsible for the direction, coordination and administration of the research program.

A science plan for the KMRP outlines the priority research and information needed to support the management of ecological and social values in the Kimberley region through joint management of the Kimberley marine park network that are the focus of the program. The plan comprises a suite of multidisciplinary research projects focused around two themes: (1) biophysical and social characterisation, to provide the foundational datasets required for marine park and marine resource management, as well as better understanding and management of current human impacts; and (2) understanding key ecosystem processes, to provide the scientific understanding of ecosystem functioning and response to a range of potential human impacts that are likely to arise in the future, including climate change.

The research program was undertaken between 2012 and 2017 and involved up to 80 scientists from eight research or management institutions in Western Australia working collaboratively on 25 research projects. Indigenous participation and engagement were key components to the success of the research program and all projects involved engagement with Aboriginal people and development of partnerships with the relevant traditional owners to include their participation and to ensure the research outcomes benefit local communities. A key outcome for the KMRP has been the delivery of knowledge to the key end users who would benefit most, including the joint managers of marine and coastal waters of the Kimberley.

### Aims

- Ensure the KMRP research projects are developed and delivered in line with the State's priority needs, and to meet DBCA and joint management strategies for the newly-formed and proposed marine parks and reserves in the Kimberley.

- Ensure integration of research projects within the KMRP, both in terms of field logistics and science findings, so that the program as a whole produces a clear understanding of Kimberley marine ecosystems and the interactions between them that is useful to management.
- Ensure that the KMRP is undertaken in a culturally appropriate way in partnership with local Aboriginal people and delivered in a way that will help their longer-term aspirations.
- Ensure that knowledge transfer and uptake occurs between scientists, joint managers and decision makers.

### Progress

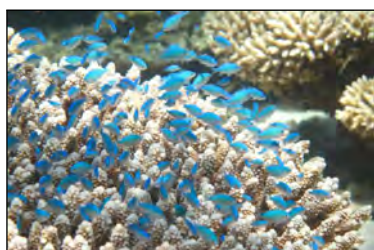
- Findings and outcomes from the KMRP were presented and discussed with DBCA end users to identify priorities for developing additional products or tools for management use.
- Findings and outcomes were communicated to representatives from seven Saltwater Country groups that participated in the program with Healthy Country management responsibilities.
- Communication of the KMRP achievements and outcomes continued through a range of activities, including presentation to the Conservation and Parks Commission, a *Landscape* article and various media engagements.
- Priority knowledge gaps that remain for the Kimberley and synergies between scientists and joint managers were identified. A presentation on this was made at the Australian Marine Science Association annual conference and a manuscript is in preparation.

### Management implications

- The KMRP outputs will increase the capacity to manage human impacts in the Kimberley marine reserves and improve understanding of the ecological and socio-cultural significance of the biodiversity assets of the Kimberley for joint managers, industry and the community. The program also enhances the capacity of Indigenous rangers and working relationships with Indigenous communities, thereby increasing the opportunity for more productive and bipartisan joint management in the future. Findings are being used in the development of a monitoring program for key biodiversity assets across the Kimberley.

### Future directions

- Undertake extension activities to deliver priority products/tools requested by key stakeholders that will assist them in using KMRP outcomes for marine and coastal management.



### Interactive effects of fishing and climate change on coral reef fish populations

SP 2009-003

S Wilson, T Holmes

### Context

Climate change and over-fishing are widely regarded as the major threats facing coral reef communities worldwide. Typically fishing has a 'top-down' effect on communities, through the removal of large predators, whilst climate change causes degradation of habitat, which affects fish that recruit, feed and shelter within corals. The independent impacts of these threats are well-studied; however, the interactive effects between fishing and climate change are yet to be examined. This interaction may be particularly important on reefs off the mid-western Western Australian coastline where per-capita boat ownership and recreational fishing pressure is extremely high.

Two critical processes that determine the community structure of coral reef fish are recruitment and early post-settlement predation. It is hypothesised that the degradation of coral-associated habitat due to climate change will cause a decline in recruit numbers. Conversely, fishing will reduce abundance of large predators and increase numbers of smaller habitat-associated predators, thereby increasing post-settlement predation. Examining how changes in habitat and predators interact and influence post-settlement survival of fish will be critical to understanding the impacts on biodiversity of fish communities and fish populations.

## Aims

- Determine how habitat degradation instigated by climate change and changes in fishing pressures affect the composition of the fish communities on Western Australian coral reefs.
- Assess diet of predatory species targeted by fishers.
- Identify microhabitats preferentially used by juvenile fish.

## Progress

- A study assessing the role of marine reserves following coral bleaching and regime shifts from coral to macroalgal states was published in *Nature Communications*. The study, based in the Seychelles, demonstrates that some reefs may not recover to pre-disturbance levels of coral cover and become dominated by macroalgae. This includes reefs in no-take marine reserves. The diversity of fish in regime shifted reefs is reduced, even when these reefs are in no-take reserves. The biomass of fish targeted by fishers remains higher in no-take reserves than on fished reefs, though the species protected by reserves changes following regime shifts to macroalgal dominated states.

## Management implications

- These findings help identify the processes that drive fluctuations in fish diversity and abundance, making it easier to discern the human impacts that can be managed locally from natural and climate related sources of variation.
- Increased occurrence of fish associated with macroalgal habitats in tropical fisheries and reduced abundance of small bodied fish, are indicative of climate changes to coral reef habitats.
- Loss of habitat essential for fish, especially small bodied species and juveniles, may reduce diversity and abundance of fish in the future, emphasising the importance of identifying and managing climate resilient habitats.

## Future directions

- This project is now complete.



## Fire Science

**Program Leader: Ben Miller** The Fire Science Program seeks to inform fire management and biodiversity conservation on lands managed by the department, which includes state forests, national parks and other conservation reserves. The strategic goal of the program is to ensure that the best available scientific information is used for integrated fire management to protect communities and natural values. Key themes for the program include developing and validating decision support tools for fire management, and understanding the effects of fire regimes on species, ecosystems and landscapes and how these interact with threatening processes including weeds, introduced predators and climate change. Monitoring and learning from the outcomes of prescribed burns and bushfire incidents is also an important activity for the program. Strong collaborative linkages exist with universities, cooperative research centres, CSIRO, the Bureau of Meteorology, other government agencies and private sector research providers.



### **Development of a systematic approach to monitoring and reporting on the outcomes of prescribed burns and bushfires**

SP 2018-134

V Densmore, L Mccaw, K Zdunic

#### **Context**

Fire severity describes the amount of biomass removed, reduced or substantially altered (e.g. charred) by either unplanned bushfire or planned burning. Severity relates to fire intensity but extends the consideration beyond fire behaviour to incorporate ecological effects and structural changes. Thus, fire severity represents a useful approach to gauge how planned burning or unplanned fire has impacted future fire hazard and the persistence of habitat for flora and fauna. A systematic tool to assess fire severity supports the objective evaluation of the outcomes of decision making and the methods used to apply planned burns and to meet statutory reporting obligations including fire management performance indicators and potential impacts on listed flora and fauna.

#### **Aims**

- Develop a framework for a systematic approach to assessing and reporting on the outcomes of prescribed burns and bushfires based on remote sensing and field survey.
- Develop and test a variety of reporting tools and metrics related to environmental outcomes.

## Progress

- Differenced normalised burn ratio (NBR) was used to remotely assess severity of prescribed burns and bushfires based on satellite imagery taken four to six weeks after fire and one year prior: compared to field assessment, NBR classification accuracy ranged from 64 to 82 percent.
- Field-based assessment tools (OzCBI) have been adapted to assess responses of forest and woodland vegetation types and heath and kwongan vegetation types to fire. Around 638 plots were assessed across seven districts and eight major vegetation types.
- The individual metrics in both the forest and heath OzCBI tools have been assessed and adapted where necessary to improve the correlation of the overall OzCBI score to the NBR.
- The field assessment tools have been developed into an Android application to facilitate efficient data collection and promote data integrity without multiple data entry steps. An R package (rOzCBI) development has also been commenced.
- Field assessment training was provided to Perth Hills district, and Southwest and South Coast Region staff.
- Preliminary severity maps have been produced for Perth Hills district.

## Management implications

- Improved ability to quantify spatial patterns of fire activity and vegetation effects will support cost-effective and meaningful reporting on the extent to which prescribed burning has achieved specified objectives and success criteria for biodiversity management, bushfire risk management and other land management values e.g. forest regeneration.
- Improved reporting will enable further research and knowledge development and contribute to refinement of the prescribed fire planning process including objectives that are measurable, achievable and relevant to particular land management values.
- Applying the same approach to quantify spatial patterns of fire activity and vegetation effects following bushfires will allow analysis of fire history drivers across vegetation types and regions and informed comparison of the effectiveness of the overall fire management program.

## Future directions

- Use field data to confirm accuracy and useability of the approach.
- Automate process to produce burn achievement and burn severity maps to incorporate within the Spatial Support System.
- Overlay severity maps with ignition patterns and species populations to support fire management and conservation decisions.



### Evaluation of synergies among fire and weed management in urban biodiversity and fire management

SP 2018-046

B Miller, R Miller

## Context

The social and conservation values of remnant natural ecosystems in urban and peri-urban environments can be significant, particularly where they include threatened species and communities, such as the nationally listed 'Banksia Woodlands of the Swan Coastal Plain ecological community'. Fire management of these systems is particularly complex as they are often: very close to homes, businesses and infrastructure; exposed to high ignition likelihoods; fragmented; subject to a wide range of other threats and disturbances; and susceptible to invasion, or already supporting a number of pest plant and animal species. The spread of grassy weeds, in particular, can be enhanced by fire, and promotes changes in fire regime. Knowledge of interactions between fire regimes and weed invasion will provide a basis for synergies in fire and weed management that may deliver



beneficial outcomes. The study design and replication, and its fuel, plant species and community response data, provide valuable research infrastructure that associated student projects and other studies can use (e.g. soil properties, invertebrate responses).

### Aims

- Assess outcomes for prescribed and wild fire management, weed management and the persistence of native plant species in urban and peri-urban areas by testing a range of fire and weed management approaches.

### Progress

- Biomass harvesting and plant allometry analysis was completed, supporting late draft *Banksia* woodlands fuel dynamics manuscript.
- Weed management continued at Kings Park, Bold Park, Jandakot and Yangebup (Beeliar) sites. The Jandakot and Yangebup sites were resurveyed.
- Treatment (burning) of the final of three experimental plots examining resprouter seedling survival of fire at two, three and four years after establishment completed with assistance from Kings Park bushland staff.
- Monitoring of seedbanks in a very long unburned woodland fragment commenced with Town of Victoria Park in a small urban remnant prior to planned restoration management burning.

### Management implications

- Identification of optimal combinations of weed and fire management treatments will provide a basis for recommendations for the management of peri-urban and urban bushlands.
- Initial results suggest poorer recovery of native species after fire when weeds are not controlled; however, post-burn weed management is also effective in maintaining low levels of weed cover.

### Future directions

- Ongoing implementation of weed treatments and survey schedule.
- Analysis of initial response data will be undertaken as a burn x weed treatment.
- Submission of *Banksia* woodlands fuel dynamics analysis manuscript.
- Second experimental phase, with burn treatment and increased pre- and post-fire monitoring and analysis.
- Commencement of an ECU PhD student project in part examining fungal community responses to fire and weed management treatments.



## Understanding the changing fire environment of south-west Western Australia

SP 2014-001

L Mccaw, V Densmore, B Ward

### Context

Fire environment is the resultant effect of factors that influence the ignition, behaviour and extent of fires in a landscape. These factors include climate and weather, topography, vegetation and fuel, and ignition. The climate of south-west Western Australia is becoming drier and warmer, and reduced autumn and winter rainfall is causing the landscape to become drier, thereby extending the duration of the traditional fire season. A combination of land use, socio-economic and organisational factors has resulted in more widespread extent of lands unburnt for two decades or more, increasing the risk of high severity fires with adverse impacts on the community and the environment. Much of the science linking interactions between climate, fire weather and fire behaviour was established in the 1960s and 1970s, and there is a need to review and update baseline information that underpins bushfire risk management and the program of planned burning undertaken by the department. This

project will draw upon data held by the department and other organisations with expertise in climate and bushfire science.

### Aims

- Provide an objective basis to review and revise management guidelines and practices based on past research and experience during wetter climate phases.
- Provide contextual information for investigations of the role and effects of fire in the south-west Australian environment.

### Progress

- A Bayesian analytical approach has been used to explore the influence of climate variability modes on fire weather conditions and lightning-ignited bushfires in the Warren Region. A manuscript has been prepared for submission to *Climate Dynamics*.
- A chapter examining the role of prescribed fire in the management of forests and woodlands in southern Australia was included in a book on contemporary issues for prescribed burning published by the Australasian Fire and Emergency Service Authorities Council.
- Two papers on prescribed burning were published in a special issue of the *International Journal of Wildland Fire*.
- A paper comparing daily forest fire danger metrics for three case study areas in the south-west of Western Australia and three case study areas in Victoria was published in the *International Journal of Wildland Fire*.
- A paper examining fire management in Mediterranean-type regions on five continents and the challenges posed by population growth and climate change was published in *Environmental Research Letters*.
- Outcomes of prescribed burning undertaken in jarrah and karri regrowth forest at Gordon forest block were assessed using remote sensing and ground-based measurements as part of an adaptive management program undertaken jointly with Warren Region and Fire Management Services Branch.
- An interim report was provided to the Wheatbelt Region for an ongoing project investigating factors and methods that promote the regeneration of *Gastrolobium* species thickets in Dryandra woodland.

### Management implications

- Understanding the factors that influence the location and timing of bushfire ignitions is important for developing effective management strategies to minimise the risks posed by unplanned fires, and to guide the level of resourcing required for bushfire suppression in different management areas. Lightning is an important cause of bushfire ignition in south-west Western Australia and the area burnt by lightning-caused fires has been disproportionately large relative to the number of ignitions during the past decade. Better understanding of the links between climatic patterns and lightning ignition could provide advance warning of above-normal activity and the opportunity for improved preparation and resource deployment.
- The increased occurrence of large and damaging bushfires in the past five years has led to a refocus on the importance of managing fuels with prescribed fire. In order to achieve a safe and effective prescribed burning program there is a need to understand how weather and climate influence opportunities for burning, and how these opportunities may be changing over time.

### Future directions

- Further evaluate and validate output from the JASMIN soil moisture model to determine its ability to quantify the dryness and availability of fuels in a variety of vegetation types.
- Collate and utilise fuel loading and consumption data for south-west Australian vegetation types to calibrate the AQFx smoke dispersion forecasting system.



## Long term response of jarrah forest understorey and tree health to fire regimes

SP 2012-029

V Densmore, B Ward

### Context

This study is a long term strategic research project to better understand the effects of fire regimes, including prescribed fire, on the floristic composition of jarrah forests. This knowledge is important for developing and implementing ecologically appropriate fire regimes and for managing fire to reduce risk to the community, biodiversity and other environmental values.

### Aims

- Understand and quantify the long-term effects of various fire regimes on the floristic composition of jarrah forests.
- Determine the long-term effects of various fire regimes on tree health and growth rate.
- Monitor potential interactions between climate change and fire regimes and their impacts on floristic composition and fire behaviour in jarrah forests.

### Progress

- A treatment burn was applied to plots at Yackelup to simulate summer fire/dry soil every 12 years. Fire behaviour observations were taken during the burn and post-fire assessment of scorch, defoliation and litter consumption were documented.
- A paper was published in *Fire Ecology*.

### Management implications

- Being one of a few long-term studies of its kind around the world, the findings of this study are important for guiding fire management policy and planning for community protection and biodiversity conservation.
- Knowledge and understanding gained from this long-term study have been incorporated into a fire ecology training program that is delivered to employees involved in fire management planning and operations.
- Within the fire frequency and intensity ranges investigated in this study, there was flexibility in the application of prescribed fire to achieve management goals without loss of plant diversity.

### Future directions

- Remeasure floristic composition and reburn plots in McCorkhill forest block.



## North Kimberley Landscape Conservation Initiative: monitoring and evaluation

SP 2012-027

I Radford, R Fairman

### Context

This project is a biodiversity monitoring and evaluation program to inform adaptive management of fire and cattle in the north Kimberley. The adaptive management program that forms the Landscape Conservation Initiative (LCI) of the *Kimberley Science and Conservation Strategy* commenced in 2011 in response to perceived threats by cattle and fire to biodiversity conservation in the North Kimberley. This initiative is based on the hypothesis that

large numbers of introduced herbivores and the impacts of current fire regimes are associated with declines of critical weight range mammals, contraction and degradation of rainforest patches, and degradation of vegetation structure and habitat condition in savannas. This monitoring and evaluation program will provide a report card on performance of landscape management initiatives in the north Kimberley, particularly prescribed burning and cattle culling, in maintaining and improving biodiversity status.

### Aims

- Inform management of biodiversity status in representative areas after prescribed burning and cattle control programs have been applied.
- Provide warning when landscape ecological thresholds have been reached, for example decline of mammals to below 2 percent capture rate, or decline of mean shrub projected ground cover to less than 2 percent.
- Compare biodiversity outcomes in intensively managed and unmanaged areas to evaluate the effectiveness of management interventions in maintaining and improving conservation values.
- Investigate cane toad and predator interactions that may influence mammal abundance.
- Elucidate influence of different burning approaches to threatened plant taxa in the North Kimberley.
- Investigate interactions between fire and weed invasion.

### Progress

- A manuscript was published in the journal *Biodiversity and Conservation* showing the benefits of prescribed burning in savannas for threatened mammals through reduction of the negative impacts of extensive late dry season wildfires.
- Modelling analyses shows that threatened mammal abundance and species richness is highest in areas with low feral cat activity, low cattle impacts on vegetation, low weed and annual grass cover and low fire intensity. Conversely threatened mammals are positively associated with increasing site ruggedness/rockiness, increasing amounts of long unburnt vegetation and high shrub cover.
- The regional mammal monitoring program is now expanding into new areas in the Kimberley and there is increasing participation in implementation of the program. Monitoring results are now routinely used in the planning of the annual fire and cattle management program.

### Management implications

- Monitoring demonstrates that increases in patchy early dry season prescribed burning benefited threatened species including the brush-tailed rabbit rat, northern quolls (in rocky habitats), the endemic Kimberley rock rat and the red cheeked dunnart.
- Conversely, some mammals including generalist rodents and northern quolls (in non-rocky habitats), respond negatively to increasing late dry season fire and positively to increases in large patches of long unburnt vegetation. This suggests that net reductions in annual burnt area will benefit these species.
- Rodent populations were more stable under prescribed burning, as fire extent is the main driver of populations and managed burning regimes are less chaotic than unmanaged wildfire dominated fire regimes.
- There is statistical evidence that the LCI has shifted fire regimes in the North Kimberley from a dominance by late dry season bushfires to predominantly early dry season prescribed burning with positive wildlife benefits.
- There is strong evidence that cattle have negative influences on critical weight range mammals, including threatened species such as the brush-tailed rabbit rat. Culling programs should be maintained and expanded in important conservation reserves.

### Future directions

- Continue monitoring to evaluate management effectiveness for threatened mammals and other groups across the Kimberley region.
- Undertake occupancy modelling to determine the response of threatened species to fire regimes and other threatening processes.



## Fire regimes and impacts in transitional woodlands and shrublands

SP 2010-011

C Yates, C Gosper

### Context

The Great Western Woodlands (GWW) is an internationally significant area with great biological and cultural richness. This 16 million hectare region of south-western Australia contains the world's largest and most intact area of contiguous temperate woodland. The GWW Conservation Strategy and a review conducted by a wide range of scientific experts identified inappropriate fire regimes as a threat to the woodlands and emphasised the need for a science-based fire management regime for the area. Critical gaps in the knowledge of fire ecology for GWW ecosystems are a hindrance for ecological fire management in the region. The GWW supports eucalypt woodlands at very low mean annual rainfall (250-350 mm). Woodland eucalypt recruitment is stimulated by fire but individuals are slow growing. In recent decades a large part of the GWW has been burnt and concern has been expressed over the ecological impacts of this. Fire ecology research already undertaken in eastern Wheatbelt nature reserves will help resolve ecological fire management issues for mallee and mallee-heath communities in the GWW, but similar information for the dominant eucalypt woodlands is needed.

### Aims

- Develop a method to robustly estimate stand time since fire in gimlet (*Eucalyptus salubris*) woodlands that have not been burnt during the period covered by remotely-sensed imagery, allowing the scale of recent extensive wildfires to be placed in a historical context.
- Investigate the effects of time since fire on the assembly and recovery of gimlet woodlands, including on plant and animal community composition, development of ecosystem structure and changes in carbon dynamics.
- Produce a spatially-explicit representation of long-unburnt woodlands through linkage of plot data on vegetation structure with remotely-sensed imagery.

### Progress

- Analysis of changes in standing dead tree and fallen woody debris, published in *Ecosphere*, showed strong responses to both time since fire and interval length between the most recent and previous fire.
- In collaboration with BirdLife Australia, the effect of time since fire on the abundance and composition of woodland bird communities and their habitat usage was assessed. Bird species responded over multi-century timescales to time since fire-associated changes in habitat composition and structure, with the findings published in *Ecological Applications*.
- In collaboration with CSIRO and Ngadju Conservation, planning commenced for vegetation structure measurements of allometry and field LiDAR samples to link with remotely-sensed imagery for the development of spatial models of woodland age-classes.
- Plant trait data from the *Eucalyptus salubris* chronosequence was provided to the AusTraits database.

### Management implications

- National-scale syntheses of temperate eucalypt woodland responses to disturbance revealed that many Western Australian woodlands are uniquely dominated by taxa that are obligate seeding, and have vegetation dynamics driven by rare, stand-replacing disturbances. These characteristics illustrate a putative vulnerability to decreases in intervals between fires; and large changes in vegetation composition and structure with time since fire and with variation in prior fire interval.
- Post-fire succession in vegetation composition and structure, which in turn determines successional patterns in animals, occurs over multi-century timescales, demonstrating the value of avoiding fire in mature woodlands to maximise future fire management options.
- Knowledge generated through this project has been incorporated into fire ecology training, information sheets and fire management information notes made available to departmental staff.

## Future directions

- Finalise journal publications concerning revised estimates of time since fire of long-unburnt gimlet woodlands and changes in carbon stocks with time since fire.
- In collaboration with CSIRO and Ngadju Conservation, implement field sampling of woodland structure with LiDAR at gimlet chronosequence plots to develop spatially-explicit models of woodland age-class based on satellite imagery.



## Burning for biodiversity: Walpole fine-grain mosaic burning trial

SP 2004-004

J Farr, B Ward, V Tunsell, A Wills

## Context

Fire management based on sound science is fundamental to the conservation of biodiversity and the protection of life and property in fire-maintained ecosystems of south-west Western Australia. There is a substantial body of scientific evidence that, within ecologically circumscribed parameters, fire diversity can benefit biodiversity at the landscape scale. We hypothesise that a fine-grained mosaic of patches of vegetation representing a range of biologically-derived fire frequencies, seasons and intensities will provide diverse habitat opportunities and can also contribute to reducing the occurrence of large, damaging and homogenising wildfires.

## Aims

- Determine whether a fine-scale mosaic of vegetation at different seral (post-fire) stages benefits biodiversity at the landscape scale.
- Develop operational techniques to use frequent and planned introduction of fire into the landscape (patch-burning) to create a fine-scale mosaic of vegetation patches at different stages of post-fire development.

## Progress

- A paper describing effects of mosaics and responses to time since fire in bird assemblages has been published in *Fire Ecology*.
- A draft manuscript describing the effects of mosaics and vegetation on epigeic invertebrate richness and trophic structure will be submitted.
- A paper describing the theory of fire-induced mosaics, how to describe and characterise mosaics, and operational challenges in creating fire mosaics has been submitted.
- A draft manuscript describing the effects of mosaics on vegetation has been prepared.

## Management implications

- This study demonstrates that fine-grain patch-burning is operationally feasible in forest areas. Although data analysis is incomplete, benefits to biodiversity at the landscape scale, especially cryptogams, invertebrates, fungi, and birds through retention of patches of a range of vegetation ages are increasingly evident. Any benefits to higher order organisms may take longer to emerge.
- Large-scale implementation of mosaic burning by the frequent introduction of fire into the landscape is being considered as a strategy for increasing community protection while protecting biodiversity. The findings of this study will provide the underpinning science for this strategy.

## Future directions

- Complete publication and prepare an overview paper covering the biodiversity outcomes.
- Develop recommendations for mosaic burning in forest areas.



## Kings Park Science

**Program Leader: Jason Stevens** Kings Park Science undertakes research in native plant biology, underpinning the conservation and ecological restoration of Western Australia's unique biodiversity, and biodiversity generally. Research is focused in the key areas of restoration ecology and ecophysiology, seed science, conservation genetics, conservation biotechnology, ecosystem ecology, fire ecology and systematics. Research is prioritised to enhance practical outcomes in conservation and management, and sustainable development of the State's unique natural resources. The Program delivers science capacity underpinning the State's botanic garden and the lands managed by the Botanic Gardens and Parks Authority, as well as the horticultural development of the Western Australian flora. The Program has a long history of successful post-graduate student supervision in collaboration with Western Australian universities, and contributes to undergraduate teaching, predominantly in conservation biology and restoration ecology.



### Seed science

SP 2018-085

D Merritt, T Erickson

#### Context

Seed science provides information to support plant species conservation and ecosystem restoration. Research is focussed on the physiology and ecology of seed dormancy, germination, and longevity, the interactions of seeds and seedlings with the soil environment, and the development of seed technologies to enhance seedling establishment in threatened species translocation and broad-scale restoration settings. Seed science is integrated with the seed banking functions of the department to support and enhance the capacity for long-term storage of germplasm of Western Australia's flora.

#### Aims

- Support and enhance the curation of *ex situ* collections of germplasm through resolving seed storage behaviour and longevity, and developing methods for assessing seed quality and predicting seed storage life.
- Develop reliable methods for seed-based propagation through determining seed dormancy-break and germination requirements.
- Develop seed enhancement technologies that improve seedling establishment for broad-scale restoration.

- Engineer efficient mechanised broad-scale delivery of diverse seed types to restoration sites, including sloped and rocky landforms.
- Inform the management of Western Australia's flora through the study of seed ecology in the natural environment.

### Progress

- Field trials were installed at mine sites in the Pilbara and the south-west testing new seed technologies and seeding machinery for a range of species across different habitats and landscapes.
- A seed flamer, designed to remove unwanted appendages from seeds to improve their handling properties continued to be developed, and three commercial-scale seed flammers have been constructed to support direct seeding trials.
- A field trial was installed in the Pilbara examining the inoculation of soils with pelletised cyanobacteria strains isolated from naturally occurring soil crusts, showing cyanobacteria can be successfully incorporated into pellets and grow on degraded soils once the pellets are distributed and watered.
- Seed dormancy-break and seed germination protocols for the threatened species *Aluta quadrata* were resolved to support future research into the management of this species and potential impacts of mining.
- Studies on the tolerance of seeds and seedlings of species of *Nymphaea* to sodium chloride were undertaken to determine their sensitivity to increased salinity.

### Management implications

- The ability to pelletise and store cyanobacteria that have shown positive effects on soil quality and seedling growth in field trials provides the potential for further development of efficient broad-acre distribution methods of these naturally occurring organisms for the restoration of degraded lands.
- The decreased germination of seeds of *Nymphaea* species following very small increases in salinity indicates that intrusion of seawater into the coastal freshwater ecosystems in northern Australia due to projected rises in sea-level is likely to significantly impact upon their seedling recruitment.

### Future directions

- Continue to support the viability testing of seed collections to inform the development of seed dormancy-break and germination protocols and the management of banked seed collections.
- Undertake additional design modifications and construction of direct seeding machinery and components for field testing across a number of representative sites in the Pilbara and south-west.
- Continue to develop and refine seed enhancement techniques including variations of coating, pelleting, and priming applicable to broad-scale restoration and evaluate their capacity to enhance seedling establishment in field trials.



### Restoration science

SP 2018-077

J Stevens, S Krauss, W Lewandrowski, C Elliott, B Miller

### Context

Restoration science is a multidisciplinary approach to provide a comprehensive scientific basis for restoration actions across the State. Overall, the research includes seed science, provenance, ecohydrology, ecophysiology, soil science, community ecology and plant-enabling technologies. Restoration science works across diverse systems including Pilbara grassland and savanna, mid-west shrublands, Swan Coastal Plain *Banksia* woodlands and shrublands, Jarrah forest, marine seagrass meadows, and arid coastal communities and collaborating with a variety of stakeholders. Restoration science is well placed to provide the applied scientific solutions required for all plant community restoration activities.



## Aims

- Establish targets and success criteria for restoration success.
- Determine appropriate sourcing of biological materials for restoration.
- Optimise establishment of plants in restoration.
- Determine factors facilitating growth and survival of plants in restoration.
- Determine factors restoring resilience, sustainability and landscape integration.

## Progress

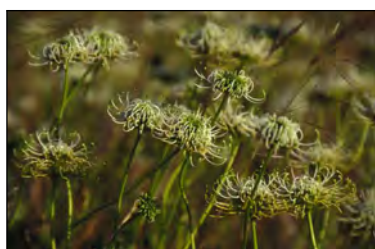
- Finalised compilation of historical site rehabilitation practices and rehabilitation outcomes for a 20 year *Banksia* woodland chronosequence. Preliminary data analysis undertaken in collaboration with UWA through the Centre for Mine Site Restoration.
- Compared the prediction power of remotely sensed hyperspectral data at different scales (leaf and canopy), for various plant species within *Banksia* woodlands, in relationship to distinct water status-related physiological variables.
- Established five translocation sites for *Tetratheca erubescens*. Undertook soil seed bank analysis on *Darwinia masonii* to assess restoration trajectory success, and plant and soil analysis on *Lepidosperma* sp. Parker Range to assist with niche definition.
- Commenced a collaborative project with the Department of Primary Industries and Regional Development assessing current Kimberley pasture systems to determine improvement strategies for both biodiversity and beef production.
- *Framework for development of post-mining completion criteria in WA* was published in conjunction with WABSI.

## Management implications

- A published framework for completion criteria development will provide clearer guidance for industry, the government regulators and the Western Australian community around mine rehabilitation closure criteria.
- Monitoring rehabilitation programs to understand impacts of rehabilitation practice on plant function at the scale now required may mean introducing new technologies to complement traditional monitoring methods. Linking rehabilitation outcomes to plant traits, as well as plant function to remote sensing spectral signatures will provide a valuable insight into the mechanisms underpinning successes in rehabilitation.
- Including native species into traditional pasture systems in the Kimberley, may not only improve biodiverse values of pasture systems but may improve grazing performance in degraded and variable (drier) systems.

## Future directions

- Continue to develop near surface remote sensing technologies and linking these to plant ecophysiological performance.
- Undertake research on the use of native pasture species in rangeland systems.



## Conservation genetics

SP 2018-068

S Krauss, J Anthony, E Sinclair, B Ayre

## Context

The conservation, restoration and horticultural development of Western Australia's unique biodiversity is informed by an understanding of patterns of genetic diversity at multiple hierarchical levels (individuals, populations, species, communities), as well as the key ecological and evolutionary drivers of this genetic diversity, such as adaptation, mating and dispersal. Conservation genetic research seeks to understand the impacts on genetic diversity and the key drivers of this diversity from environmental stressors such as habitat fragmentation, climate change, and introduced species, and identify solutions based on genetic data and theory.

## Aims

- Experimentally assess seed sourcing strategies for improved restoration outcomes.
- Assess the conservation and evolutionary consequences for plants pollinated by vertebrates.
- Assess reproductive functionality in restored plant communities.
- Experimentally assess the resilience of plant populations to environmental stressors.
- Assess responses of the soil microbiome through ecological restoration.

## Progress

- Fully reciprocal provenance trials with 3,200 seedlings of *Eucalyptus todtiana* from four sites from across the Swan Coastal Plain showed little effect of provenance for seedling growth and mortality, but a strong effect of trial site on seedling performance. Analysis of mating systems in these source populations show equivalent parameters of genetic quality of seed.
- Pollinator exclusion experiments showed that exclusion of birds as pollinators for *Banksias* and kangaroo paws significantly impacts plant fitness. For catspaws, the predicted high mate diversity for bird pollinated plants was not found, highlighting that herbaceous species may differ from tree species.
- Multiple natural and restored plant populations have been sampled for an ecological genetic assessment of reproductive functionality following ecological restoration.
- Long-term reciprocal transplant experiments, *ex situ* controlled stress experiments and stress-related gene expression analysis of seagrass in Shark Bay continues. Survival and growth rates at 2.5 years following establishment of a long-term replicated reciprocal transplant experiment for *Posidonia* in Shark Bay (four sites, two different establishment seasons) show strong plastic, rather than local adaptation, responses to environmental variability in salinity and temperature, with site specific responses associated with variable predation. An *ex situ* controlled stress experiment was conducted and data are being analysed.
- The diversity and composition of soil microbial communities following post-impact rehabilitation in the jarrah forest were assessed using eDNA, and contrasted to plant community transition patterns. While restored soil bacterial communities quickly returned to the pre-disturbance state, soil fungal communities closely tracked plant community trajectories toward the pre-disturbance state, but were short of targets even after 30 years.

## Management implications

- Provenance trials continue to suggest that diverse local provenance seed provides resilience to current and future climates for restored plant communities of *Banksia* woodlands. Consequently, genetically diverse seed for restoration should continue to be sourced locally.
- Seagrass meadows, although impacted by extreme climate events, show a resilience to climate change that suggests local diverse sourcing of propagules provides for effective restoration.
- Refined understanding of the critical importance of vertebrates for pollination indicates control of feral honeybees (*Apis mellifera*) may reduce negative pollination impacts on native flora.
- Enhanced knowledge of soil biota trajectories through post-disturbance restoration shows soil management needs to be improved to enhance the return to pre-disturbance communities, and identifies key missing elements that may suit inoculation.

## Future directions

- Undertake analysis of pollinator exclusion in *Banksia* woodland sites.
- Undertake *in situ* reciprocal transplant trials in Shark Bay, transcriptome population genomic analysis, and controlled *ex situ* stress manipulative experiments.
- Undertake provenance trials, glasshouse trials, and seed germination trials for key species for ecological restoration of *Banksia* woodlands.
- Assess restoration success of *Lambertia multiflora* through genotyping of seedlings.
- Assess post-mining restoration chronosequences for bacterial and fungal community composition and diversity.



## Orchid conservation and recovery

SP 2018-060

B Davis, J Stevens

### Context

Western Australia is an orchid biodiversity hotspot of worldwide significance, with an estimated 400 species of orchid, many of which are endemic. There are currently 41 Western Australia orchid taxa listed as threatened, with the key threatening processes being habitat loss due to land clearance and fragmentation, loss of pollinators, weed invasion, illegal collection and habitat degradation. Orchids represent a conservation challenge as they have complex and sometimes highly specific ecological interactions with pollinators above ground and their mycorrhizal partners below ground. Overlaying the immediate needs of the orchid are the independent requirements of the pollinator (nectar sources, brood sites) and the mycorrhizal partner (carbon sources, soil attributes). *Ex-situ* conservation of Western Australia's orchids is undertaken through maintaining a large living collection of orchids, seed banking orchid seed and maintaining an orchid mycorrhizal library. This collection provides a basis for orchid translocations, through to propagation, outplanting and monitoring in the form of experimental research and species recovery.

### Aims

- Determine and prioritise those orchid species most at threat and undertake *ex-situ* conservation actions leading to supplementation of natural populations, to ensure their ongoing persistence.
- Continue maintenance and growth of the *ex-situ* living collection, seed and fungal collections.
- Conduct integrated conservation research to provide management solutions to improve the conservation status of threatened orchid taxa.
- Make collections of seed and fungi from *Caladenia lodgeana*, *C. procera* (critically endangered) and *C. viridescens* (endangered) to investigate the potential for supplementation of wild populations and *ex-situ* storage.

### Progress

- A further 900 *C. busselliana* seedlings were propagated and are currently in transition from laboratory to glasshouse.
- Ongoing monitoring of nine hundred *C. busselliana* seedlings emergence.
- Newly collected fungal isolates and seed sources were tracked for germination performance and survival in *C. busselliana*.
- A total of 460 *C. procera*, 180 *C. viridescens* and 860 *C. lodgeana* seedlings have been successfully transferred from the laboratory to the glasshouse.
- Surveys across the extent of *C. lodgeana* and *C. busselliana* provided updated numbers on population size and new plants.
- First pollinator surveys completed for *C. busselliana* and *C. lodgeana*.
- Optimisation of germination protocol for *Thelymitra variegata*, which will be transferrable to other *Thelymitra* species.

### Management implications

- The *ex-situ* collection of *C. busselliana* continues to grow and provides essential conservation support for this critically endangered species with total plant numbers and genetic diversity now increased many times over.
- Growing *ex-situ* collections of other threatened orchids (*C. viridescens*, *C. lodgeana* and *C. procera*) of the Capes region provides conservation support for species with dwindling or singular populations that are at threat from stochastic events.

- First indications of the identity of *C. busselliana* and *C. lodgeana* pollinators provides information on the types of habitats and likely food plants being utilised by pollinators.
- Updated population numbers and the discovery of new plants of *C. busselliana* and *C. lodgeana* provides vital demographic and location data to better manage populations of these threatened orchids.
- Development of a germination protocol for *T. variegata* provides conservation support to this and other threatened *Thelymitra* species. This advancement brings the possibility of translocations as a conservation tool for the genus *Thelymitra*.

### Future directions

- Optimise propagation protocols across orchid genera to increase supplementation success from laboratory to *in-situ* site.
- Monitor translocations to test survival of different aged seedlings and season of release.
- Develop protocols for cross-pollination, seed collection and fungal collection in small orchid populations.
- Increase the diversity of orchids and optimise growing conditions for plants from the living collection to be used as a seed orchard.



### Conservation biotechnology

SP 2018-048

R Bunn

### Context

Research into *in vitro* and cryogenic science streams is essential to progress and enhance the *ex situ* conservation and germplasm storage options for threatened plant species. The micropropagation of threatened taxa also provides a source of greenstock for plant translocation studies in cases where normal propagation is not possible. A range of species are kept in liquid nitrogen storage for conservation and research purposes, including many rare and threatened vascular plant taxa, as well as seeds and mycorrhizal fungi of many native orchid species (including a number of rare taxa).

### Aims

- Conduct research on micropropagation of rare and threatened plants for *ex-situ* conservation.
- Undertake research on development of cryopreservation protocols for *ex-situ* conservation of threatened plants and long-term storage of germplasm of selected species.

### Progress

- *Banksia ionthocarpa* ssp *chrysophoenix* is a small prostrate shrub only occurring in open kwongan shrubland in the South-West Botanical Province ecoregion of Western Australia. It is a vegetatively propagating taxon (no seed has so far been detected), represented by four small populations comprising 16 genotypes in total. Attempt to tissue culture the remaining genotypes and establish *ex situ* germplasm collections of the species has been made. Culture lines of some of the genotypes have been established however progress has been hampered by difficulties in maintaining healthy cultures once initiated.
- *Banksia montana* is an endemic species from the Stirling Range National Park and has experienced major decline in its native habitat. Tissue culture lines have been established and research continues on developing a viable method for establishing whole rooted plants to soil.
- *Eucalyptus argutifolia* (Wabling Hill mallee) occupies a small number of limestone ridges and outcrops along the Swan Coastal Plain. Three trees were designated for micropropagation based on imminent threat from limestone mining. All three plants have been successfully established in tissue culture and one genotype established in soil.

### Management implications

- In vitro propagation provides a 'safety net' for threatened species in need of protection off-site where seed is unavailable and conventional vegetative propagation does not work or is not possible. This approach creates a secure off-site repository of genetic material (storage at room temperature, 8-14 °C) for threatened plant populations that can later be utilised to provide plants for translocations to alternative *in-situ* sites or re-stock existing declining plant populations.
- Cryopreservation (storage in liquid nitrogen -196 °C) provides additional long term, stable and biosecure storage of shoot tips, protocorms, seeds and other material of threatened plant species, that can also be revived and utilised to produce plants for restoration purposes.

### Future directions

- Continue *in vitro* and cryogenic research for *ex-situ* conservation.
- Continue to research and provide non-conventional solutions for the storage of germplasm for threatened species.



## Perth Zoo Science

**Program Leader: Peter Mawson** Perth Zoo Science Program undertakes targeted research to support the Native Species Breeding Program and the breed-for-release efforts for seven threatened species. It also addresses knowledge gaps in our understanding of behaviour, reproductive biology and conservation medicine for the species in the Zoo's collection and smaller number of species in the wild. The research program involves projects dealing with our sustainable environment and environmental communication and socio-ecology.



### Western ground parrot husbandry

SP 2018-137

A Ferguson

#### Context

The western ground parrot (*Pezoporus flaviventris*) is listed as critically endangered and is now restricted to a single population around Cape Arid. Less than 150 birds remain in the wild, and the parrots are threatened by foxes and feral cats, and habitat critical to the species survival is under threat from extensive wildfires. In July 2014, seven western ground parrots were transferred from departmental aviary facilities near Albany to Perth Zoo to attempt successful breeding to help establish a captive insurance population and to investigate the potential for future breeding for release.

#### Aims

- To determine if the western ground parrot can successfully breed in captivity, as this knowledge will inform future recovery actions.
- To develop and document captive breeding techniques that maximise reproductive output for western ground parrots, while also taking the opportunity to learn as much as possible about the biology and behaviour of the species.

#### Progress

- The five birds (two males and three females) that were added to the breeding colony in late 2018 have all settled into captivity well.

## Management implications

- Relatively little is known about this highly cryptic species and the information collected is valuable to those working with the species in the field.
- The successful breeding of western ground parrots in captivity will provide an insurance population from which birds can be used to supplement the extant population in Cape Arid National Park and provide a source of birds for reintroduction to former populations and localities in the Fitzgerald River National Park and areas west of Albany.

## Future directions

- Establish successful breeding husbandry regimes to take advantage of the newly expanded genetic base to the colony.



## Using dataloggers to determine the effects of handling and temperature on packages travelling along Australian postage routes used to illegally transport native fauna

SP 2018-128

P Mawson

## Context

Veterinary staff at Perth Zoo are responsible for treating some of the native fauna (predominantly reptiles) recovered from wildlife seizures, including those that have been smuggled through the Australian domestic postal service. Knowledge of the forces and temperatures an animal is likely to have experienced will be beneficial in the assessment of the animals' health and welfare, and contribute to the decisions that inform the treatment plan.

## Aims

- Use dataloggers to determine the temperatures and forces reptiles are likely to have experienced while being transported by post during illegal smuggling activities.

## Progress

- Data loggers were posted to five DBCA regional offices (Kununurra, Broome, Karratha, Denham and Kalgoorlie) and returned via the same mail service during early February and early March 2020.
- Data logger performance was variable, but data were obtained from four routes.
- Preliminary analysis of temperature data indicates parcel post packages are managed within a very limited and moderate temperature range, consistent with the use of air-conditioned transport modes and mail depots.
- Analysis of the data on the forces that packages were subjected to is yet to be completed.

## Management implications

- Gaining specific information regarding the temperature and forces applied to packages travelling along postage routes from remote Western Australian towns in the Kimberley, Pilbara and Goldfields that are known to be used by wildlife smugglers, will provide evidence as to the nature and extent of conditions animals are subjected to during transit. This knowledge will assist in the treatment of affected animals, and may also inform decisions related to prosecutions and potentially may influence sentencing of convicted offenders.

## Future directions

- Analysis of 2020 data will be progressed.



## Olfactory and auditory based behavioural enrichment for Perth Zoo's Asian elephants

CF 2018-119

P Mawson, E Polla

### Context

Keeping charismatic mega fauna such as Asian elephants is challenging. Elephants are intelligent, social and long-lived. Managing their welfare and ensuring that they are provided with the best standard of care requires a detailed knowledge of their behaviour. Despite a long history of domestication and keeping in captivity, little research has been conducted into the sensory and cognitive function in elephants. Examining the various components of their behaviour with carefully designed research programs allows us to understand the limits of their intelligence and to be able to modify husbandry and behavioural enrichment programs in order to provide optimal welfare conditions for the elephants.

### Aims

- Investigate the sensory functions of Asian elephants.
- Use existing methods for auditory behavioural cue presentation to determine if Asian elephants will respond to an unfamiliar human voice.

### Progress

- Olfactory trials using a standardised scent have commenced for a bull elephant and a cow elephant. Both elephants have shown motivation and calm, attentive behaviour during these trials.

### Management implications

- Knowing the capacity of Asian elephants to identify and discriminate between scents or sounds will provide important information that can be incorporated into enrichment programs to maintain or improve the welfare of captive elephants.

### Future directions

- Repeat the olfactory trials using a standard scent, rather than a varying one.
- Commence the auditory trials.



## Memory of recent actions in large-brained mammals (*Elephas maximus*)

CF 2018-118

C Holland, P Mawson, E Polla

### Context

Animals survival depends on how good, and timely the solutions to the problems are. Sometimes these problems are widely spaced in time so a problem-solving strategy that is not retained in their memory does not provide much of a cognitive economy to the individual. Among terrestrial mammals, elephants share the unique status, along with humans and great apes, of having large brains, being long-lived and having offspring that require long periods of dependency. Studying the memory of an Asian elephant may allow greater insights into the evolution of cognitive abilities in large brained animals.



## Aims

- Determine if an Asian elephant is capable of understanding an abstract rule such as the 'repeat' command.
- Determine if an Asian elephant is capable of discriminating and identifying past actions and performing responses that clearly reveal the extent to which past actions were identified and remembered.
- Determine the ability of an Asian elephant to represent their own recently performed behaviours in working memory.
- Determine the ability of such representations to affect future behaviours.

## Progress

- The bull elephant has completed control trials, and type A trials where behaviours previously trained to the repeat cue have been tested. Type A trial results have been analysed, with results suggesting that the elephant is capable of understanding the repeat cue.
- These results have led to the completion of type B trials, which contain the addition of one 'novel' behaviour attached to the repeat cue per trial, and type C trials where the repeat cue is presented twice after specific behaviours. Further analysis is required.
- The elephant has shown motivation and calm, attentive behaviour during all of these trial types.

## Management implications

- Determining the extent of an Asian elephant's memory and the capacity to apply abstract rules will inform the types of training and enrichment that can be applied to this species in the zoo environment.

## Future directions

- Undertake data analysis.
- Undertake trials involving behaviours that have never before been linked to the abstract rule to test the elephant's understanding of the abstract rule in an unfamiliar context.



## Behavioural observations of Perth Zoo collection animals for animal welfare purposes and establishment of baseline data

SP 2018-115

P Mawson, E Polla

## Context

Maintaining or improving animal welfare is a key consideration in operations at Perth Zoo, and behavioural observations of collection animals is a means of ensuring effective management approaches. Many observational studies conducted on Perth Zoo collection animals in the past have provided staff with insight into animal behaviour and generated recommendations on how to improve quality of life (e.g. through specific enrichment or modifications to enclosures or husbandry practices), as well as data to allow comparisons to be made for individual animals over time.

## Aims

- Determine what behaviours are exhibited by certain individuals or species of Perth Zoo's animal collection, and at what frequency.
- Compare current data with past studies to see if animal behaviour has changed from what might be expected over time.
- Observe the effects of the current behavioural enrichment programs on behaviour in Perth Zoo's collection animals.
- Observe the effects of Perth Zoo visitors on the behaviour of Perth Zoo's collection animals.

## Progress

- A methodology for data collection has been created that is suitable for behavioural observations for all nocturnal house animals. Analysis of behavioural observations revealed the negative impact of short-eared rock-wallaby presence on bilby behaviour. The short-eared rock-wallaby was relocated from the nocturnal house to an off-display enclosure to improve bilby welfare.
- Observations have been completed and analysed on the nocturnal house dibbler's behaviour, revealing an increase in out of sight behaviour in response to increased Zoo visitor density.
- The tawny frogmouth's behaviour has been recorded, with comparisons made pre- and post-change in exhibit lighting.
- Behavioural observations of the new slow loris have been conducted.
- Methods including a behavioural ethogram, recording method and exhibit map have been created for the Javan gibbons. Observations were completed in 2017 and again in 2019, revealing a decrease in stereotypic behaviour for a young male gibbon and an increase in the diversity of positive interactive behaviours with his older sister over time.
- Data from behavioural observations on both Sumatran tigers (revealing a relationship between exhibit swapping and stereotypic behaviour) has contributed to a new enrichment regime. The new exhibit swapping enrichment regime for the Sumatran tigers has been observed, with data analysed and a report produced outlining the findings.
- The solo lioness and two hyenas were monitored during the construction of the adjoining exhibit and the lioness's introduction to the new exhibit. Since the introduction of the two new lionesses to the Zoo collection, behaviour of the three lionesses has been monitored to determine the influence of human activity and the close proximity of neighbouring lionesses on behaviour. These observations have concluded.
- Data from behavioural observations of coati and squirrel monkeys was collected whilst the two species were housed in separate exhibits and when the two species were housed together. These observations have concluded and the squirrel monkeys and coatis continue to be housed separately.
- A team of docents have been trained to review overnight Asian elephant CCTV footage and to record the sleeping habits of the elderly female elephant. This team of docents will continue in this role long-term to monitor any changes in these variables as the elephant ages. Docents have also been trained to record nocturnal behaviour for Asian elephants using CCTV footage. Baseline data is being recorded to determine the nocturnal activity for each individual.
- An ethogram and exhibit maps were designed to record the behaviour of a male orangutan with emphasis on enrichment use, activity levels and stereotypic behaviours. Data has been analysed and provided to Life Sciences staff to inform management and welfare decisions.
- Behavioural observations have taken place on mother/offspring pairs of orangutans with a particular focus on the use of enrichment items. Docents liaised with keepers to accurately record the types of enrichment offered on any given day so that potential patterns in the data regarding food type and placement could be investigated. Observations have been recorded regarding the interactions between mother offspring pair as the offspring nears the age of wild dispersal.
- Observations have been recorded throughout the African savannah exhibit to gain information on the behaviour and location of animals. These observations have been designed to also provide information on the visibility of the African Savannah collection animals from specific visitor viewing areas. Data has been analysed and a report outlining the findings has been produced.
- The pair of golden lion tamarins have been observed with a focus on copulatory behaviours. Observations have concluded.
- A white cheeked gibbon group has been observed to study the interactions between individuals during the development of a born offspring. Data has been collected as the offspring ages and observations have concluded.
- The adult male and female binturong have been observed to examine the interactions between the two binturongs as well as any interactions the binturongs have with the otters in their mixed-species exhibit. Observations have led to the addition of a new nest box. A diet change has also been implemented. Preliminary data analysis revealed that the adult binturong have spent less time interacting with each other (including being in close proximity to each other) since the addition of the new nest box. The female binturong has successfully given birth to two offspring in the new nest box. Observations were continued to monitor the behaviour of the adult binturongs and the development of the binturong kits.
- Observations have been conducted from multiple locations in the bushwalk to determine what factors influence the use of different bushwalk areas by the macropods. Information on the location of wallabies

and red and grey kangaroos is being recorded as well as other variables such as visitor density and noise intensity, temperature, weather and other noise conditions. Preliminary analysis suggests that the density of Zoo visitors influences the location of macropods within the bushwalk, with a greater number of macropods utilising deeper retreat areas when the visitor numbers within the bushwalk were higher. Due to Perth Zoo's closure in response to COVID-19, the unique opportunity was taken to gather data on the behaviour of bushwalk macropods when no Zoo visitors were present.

- Observations took place for a project designed to collect baseline information on the location and behaviour of African savannah and Asian rainforest animals during the Zoo's closure. The main aim of these observations is to determine the effect of visitor presence on animal behaviour and location. This will be achieved by comparing data collected during the Zoo closure period and data collected in the future when standard visitation returns to Perth Zoo.

### Management implications

- Empirical behavioural data gathered through this project allow Perth Zoo staff to make informed decisions about animal welfare changes as animals age or respond to new or altered dietary regimes; monitor animals during introductions of new exhibit mates or breeding animals; validate enrichment programs; quantify animal use of exhibits before and after redesign; and measure visitor interaction with exhibited animals and the uptake of interpretation materials provided to visitors.

### Future directions

- Monitor animal behaviour in those areas of possible concern where the reduction in visitor presence associated with COVID-19 and the return of visitors may have an impact on animal welfare.



### **Geocrinia frog breed and rear for release program**

SP 2018-102

P Mawson, C Lambert

### Context

There are two species of *Geocrinia* frogs, *Geocrinia alba* and *G. vitellina*, that have a restricted distribution in south-west Western Australia and are listed as critically endangered and vulnerable. Whilst these frogs lay large clutches of eggs, the survival rate to adult frogs is low. Captive rearing of eggs to metamorphs is an effective means of overcoming this constraint and providing supplementation of animals into the populations. Egg clutches of both species are collected from the wild at the request of the Recovery Team and metamorphs are raised and subsequently released to the wild. There is ongoing research and husbandry management to achieve regular and reliable captive breeding in both species.

### Aims

- Breed and rear white-bellied and orange-bellied frogs for release to sites approved by the *Geocrinia* Frog Recovery Team in order to maintain or increase the current extent and viability of populations of these species.

### Progress

- A captive breeding colony of *Geocrinia alba* and *G. vitellina* was maintained. Egg clutches of both species were collected from the wild and metamorphs raised to 11 months of age, at which point they were released to the wild.
- 212 *Geocrinia alba* and 104 *G. vitellina* juveniles were released into sites in conservation estate east of Margaret River.

- A review of the conservation status of all Australian native frog species was published. This review provides an opportunity to review current management and research priorities for the three species of Western Australian frog that are listed as threatened species, and will inform management decisions into the future.

### Management implications

- Captive-bred and reared frogs have provided the best, and in most cases the only, means of increasing the number of individuals in a sub-population, and bolstering the genetics of isolated populations.
- Knowing the upper thermal limits for successful larval development in the two *Geocrinia* species will allow much more informed decisions about which field sites are chosen for the release of juvenile frogs to augment existing, or create new populations.

### Future directions

- Continue production of metamorphs for *G. alba* and *G. vitellina*.



### Western swamp tortoise breed for release program

SP 2018-101

P Mawson, C Lambert

### Context

Western swamp tortoises (*Pseudemydura umbrina*) are ranked as critically endangered and occur in only two natural populations at very low numbers. Establishing new populations entirely with wild caught tortoises is not feasible and captive breeding provides a source of animals for supplementation of wild populations and establishment of new populations. Captive-bred tortoises have enabled new populations to be established at Moore River Nature Reserve and Mogumber Nature Reserve. Two additional captive insurance populations have also been established at Adelaide Zoo and Monarto Zoo (South Australia) to reduce the risks associated with keeping half the global population of western swamp tortoises in a single facility.

### Aims

- Produce a minimum of 30 hatchling tortoises (> 30 days of age) each year, that are grown on until they are three to four years of age, then reintroduced into sites approved by the Western Swamp Tortoise Recovery Team.

### Progress

- Seventy-three western swamp tortoise juveniles were released into swamp habitat at Moore River Nature Reserve.
- A total of 100 eggs were produced in the captive breeding colony, 57 of which hatched.
- Analysis of growth data on western swamp tortoises released into a conservation introduction site 350 km south of Perth indicated that while survival was high, those tortoises were not able to gain weight due to low winter and spring water temperatures that affected metabolic activity, food availability and foraging opportunities. As a result the remaining tortoises that could be located were recaptured and this site has been abandoned for further releases and a search commenced for more suitable alternative southern release sites.

### Management implications

- Identification of suitable alternative release sites in the south of the State will facilitate the establishment of new populations of western swamp tortoises through assisted colonisation or conservation introductions. Site identification requires information on suitable water temperatures and availability of key aquatic invertebrate species that provide food for the tortoises sufficient to grow and be able to reproduce.

### Future directions

- Continue to produce juvenile animals for release to sites.
- Undertake research into the nesting ecology of western swamp tortoises using wild and captive populations.



### Dibbler breed for release program

SP 2018-099

P Mawson, C Lambert, A Friend

### Context

Dibblers (*Parantechinus apicalis*) are ranked as endangered and were formerly widely distributed along the west and southern coasts of Australia; however, now have a limited area of occupancy in the south-west and on islands off the midwest coast. Establishing new populations entirely with wild caught dibblers is not feasible and captive breeding provides a source of animals for supplementation of wild populations and establishment of new populations. Dibblers are one of the species intended for reintroduction to Dirk Hartog Island following cat and goat eradication, and this will be achieved through captive breeding of animals sourced from the midwest islands.

### Aims

- Maintain a captive breeding colony of dibblers to produce stock for translocation.
- Translocate captive-bred animals to establish further self-sustaining populations.
- Carry out genetic monitoring and management of reintroduced populations.

### Progress

- Twenty-four juvenile dibblers and two adult dibblers surplus to breeding requirements, were released onto Dirk Hartog Island National Park. This was the first release of this species onto the island.
- An additional two males and one female were collected from the wild on Boullanger Island near Jurien Bay as part of the foundation breeding stock and added to the captive breeding colony.
- These new animals were settled into captivity and paired for breeding. Thirty pouch young were produced from those pairings and are developing normally.

### Management implications

- The release of dibblers onto Dirk Hartog Island National Park is the first phase of a program to establish a new wild population.

### Future directions

- Maintain the size of the dibbler breeding colony to 10 pairs.
- Provide additional dibblers for release onto Dirk Hartog Island National Park.
- Continue to work on husbandry strategies to increase the reproductive output from the colony to expedite the release program.



### Numbat breed for release program

SP 2018-098

P Mawson, C Lambert, A Friend

## Context

Numbats (*Myrmecobius fasciatus*) are ranked as endangered, and occur in only two natural populations at very low densities. Establishing new populations entirely with wild caught numbats is not feasible and captive breeding provides a source of animals for supplementation of wild populations and establishment of new populations. A captive breeding program for numbats at Perth Zoo has been in place since 1992. Captive-bred numbats have enabled new populations to be established at Boyagin Nature Reserve, Battaling Forest and fenced reserves at Perup, Dryandra, Mount Gibson Sanctuary in Western Australia, and at Yookamurra Sanctuary (South Australia) and Scotia Sanctuary (New South Wales).

## Aims

- Produce yearling numbats in sufficient quantity to support proposed reintroductions to sites approved by the Numbat Recovery Team.

## Progress

- Produced 10 yearling numbats for release into the Dryandra Woodland to augment the population.
- Four adult numbats surplus to the requirements of the breeding program were also released into Dryandra Woodland.
- Two males and one female were provided to the program from Dryandra Woodland to maintain the genetic integrity of the breeding program.
- Produced 11 pouch young as part of the the 2019-2020 breeding season, with all young developing normally.

## Management implications

- Breeding of numbats provides animals to supplement existing numbat populations and establish new populations across the former range of the species. The program also aims to ensure the genetic viability of populations through monitoring genetic diversity and undertaking supplementary releases to enhance population genetic diversity.

## Future directions

- Continue to produce numbats through captive breeding.



## Survival and dispersal of black cockatoos in south-west Western Australia

SP 2018-025

P Mawson

## Context

There are three taxa of black cockatoos (*Calyptorhynchus* spp.) endemic to south-west Western Australia. All three are listed as threatened (two endangered, one vulnerable), and all have national recovery plans. This project is designed to capture additional information on the ecology of all species and monitor recruitment in the wild. Monitoring survivorship of rehabilitated birds once released back into the wild is also undertaken.

## Aims

- Monitor the recruitment of Carnaby's cockatoo at a number of sites across the species' range.
- Measure the health of nestlings of Carnaby's cockatoos at a number of sites across the species' range.
- Determine the availability of suitable nest hollows for Carnaby's cockatoo and investigate the value of artificial nest hollows to increase recruitment in the wild.
- Following veterinary treatment and rehabilitation, monitor the survival and dispersal of rehabilitated cockatoos (all three species) at release sites across their respective ranges.

## Progress

- Banding was undertaken for 139 (123 as pullus and 16 rehabilitated) Carnaby's cockatoos, along with 44 forest red-tailed black cockatoos (1 yearling and 43 rehabilitated).
- Sixty-five Carnaby's cockatoos and 12 forest red-tailed black cockatoo were either retrapped/recovered, had their bands/ colour bands photographed in the field and their band number read or inferred. Only one of those band recoveries involved a bird that was dead.
- A research paper describing the implications of *Banksia* seed reward for conservation and management of Carnaby's cockatoo on the Swan Coastal Plain was published in the *Australian Journal of Zoology*.
- A research paper describing a predation event by a south-west carpet python on a Carnaby's cockatoo nestling and adult and the likely importance of this type of food source to the pythons was published in the *Australian Zoologist*.
- A research paper describing the value of artificial nest hollows to Carnaby's cockatoos and their potential as a short-term solution to limits in availability of natural nest hollows was published in *Biological Conservation*.
- A research paper that examined the conservation value of environmental offsets to Carnaby's cockatoos was published in *Pacific Conservation Biology*.
- A research paper on the relationship between the habitat use and regional movements of Baudin's cockatoos was accepted for publication in *Wildlife Research*.
- A research paper describing a new wildlife disease syndrome in Carnaby's cockatoos was published in *Journal of Wildlife Diseases*.
- Analyses of banding data for Carnaby's cockatoo to determine a more accurate annual survival estimate was continued, along with annual survival estimates for rehabilitated Carnaby's and forest red-tailed black cockatoos.
- Work has also commenced on a manuscript describing the costs of rehabilitating black cockatoos, relative to other types of conservation action.
- Participated in a NESP Hub research project workshop using expert elicitation to inform biodiversity offset priorities for black cockatoo conservation, using the three south-west black cockatoos as case studies.

## Management implications

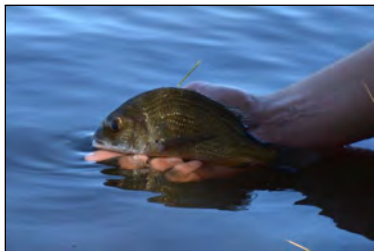
- This project has seen the successful release of 591 leg-banded rehabilitated cockatoos from three species (299 Carnaby's cockatoo, 43 Baudin's cockatoo and 249 forest red-tailed black cockatoo). The total number of cockatoos banded (all species and all ages) is now 1,733 from 17 years of work. The rehabilitation techniques and release protocols currently in use provide very high survival rates. Confidence is supported by satellite telemetry of rehabilitated birds that have been released along with the continued sighting of banded rehabilitated birds in the field. Given the high survival rates, this conservation action has an important role to play in the management of black cockatoos.

## Future directions

- Complete assessment of the costs-benefits associated with the rehabilitation of black cockatoos and prepare a manuscript for publication.
- Determine costs associated with the deployment of artificial nest hollows in comparison to the repair of degraded natural nest hollows.
- Investigate historical and current survival estimates for Carnaby's cockatoo, and determine the survival estimates for rehabilitated Carnaby's and forest red-tailed black cockatoos.

## Rivers and Estuaries Science

**Program Leader: Kerry Trayler** The Rivers and Estuaries Science Program undertakes and supports research across a wide range of disciplines to address knowledge gaps and inform management of the Swan Canning Riverpark. Research is aligned with the Swan Canning Research Strategy and WAMSI estuarine research priorities. Strong collaborative linkages exist with universities, research centres and other government departments. Scientific advice and support is provided to the Rivers and Estuaries Branch in relation to waterway condition, management, and incident response including algal blooms, fish-kills, sewage overflows and dolphin deaths.



### Apply acoustic technologies to investigate fish communities and movement

SP 2020-029

S Hoeksema, J Baker, J Watsham, K Trayler

#### Context

How fish utilise the Swan Canning Estuary, including distances moved on a daily or seasonal basis and movements in response to changes in environmental condition, remains a key knowledge gap despite a number of detailed studies on fish biology and ecology over the past three decades. This information is particularly important in relation to recreationally targeted fish species that have high value in the Perth community.

Acoustic technology can be utilised to provide valuable information on fish movements relative to water quality, such as salinity and dissolved oxygen, and to major interventions within the river system, such as the Swan Canning Oxygenation Program and the Kent Street Weir fishway. Acoustic technology can also be employed to understand how fish utilise habitats of differing complexity, particularly those that are not suited to traditional sampling methods.

#### Aims

- Utilise acoustic technology to assess fish communities and movement relative to water quality, habitat complexity and in-river interventions.

#### Progress

- The Swan Canning Acoustic Array, which consists of 30 acoustic receivers deployed throughout the Swan Canning Estuary, has been in operation since 2016. Quarterly data downloads were undertaken in 2019-20



to complement earlier downloaded data sets.

- Since its deployment, 120 black bream have been acoustically tagged and their movements tracked.
- Movement data has been used to track fish passage through the Kent Street Weir fishway and used in reporting on the fishway's influence on fish communities in the Canning Estuary and Canning River.
- Reports on the use of acoustic technology to examine how fish utilise different habitats and respond to oxygenation in the Upper Swan Estuary are currently under review.

### Management implications

- Acoustic receiver technology has shown that tagged black bream have moved through the Kent Street Weir fishway since it was commissioned in June 2018.
- Surveys of the Middle and Upper Swan Estuary using a biosonic echosounder and split-beam transducer indicated that fish avoid areas of low oxygen and highlighted the importance of oxygenation plants for improving habitat.
- The use of sidescan sonar to identify and map areas of differing habitat complexity through the Middle and Upper Swan Estuary suggested that these habitats may provide differing roles in supporting fish communities. Acoustic technology may prove useful to supplement current fish community monitoring (Fish Community Index), particularly in habitats not suited to traditional netting methods.

### Future directions

- Continue to assess movement data collected to date by the Swan Canning Acoustic Array and relate to water quality data collected through routine Swan Canning Water Quality Monitoring and data generated by the Estuarine Response Model.
- Undertake targeted tracking investigations with an initial focus on further understanding of movements around the Kent St Weir fishway.



### Investigate habitat connectivity in relation to environmental flows and barriers

SP 2020-028

S Thompson, K Trayler

### Context

The Swan-Canning river system is a salt-wedge estuary with many freshwater tributaries that have high biodiversity values. Historically, many of these tributaries have been impounded for water supply purposes and with a growing urban population there are increased demands for water. Finding the balance between the public water supply system and environmental requirements for water is increasingly challenging in a drying climate. It is important to understand the water requirements of freshwater dependent systems in terms of volume, timing, duration, and intensity of flow to adequately protect them. In addition, once these are determined and set it is important to ensure that the provisions are being met, values maintained and expected outcomes are being achieved. The latter includes consideration of how in-stream barriers can be managed to maximise value of the flow provisions.

### Aims

- Identify freshwater dependent biomes of ecological significance within the Swan-Canning river system, threatening processes, water requirements and potential for supplemental flows.
- Determine if there are detrimental impacts to ecosystems downstream of public water supply dams or water abstraction points.
- Determine connectivity of critical habitat and assess impacts of impediments to freshwater flows and to movement of riverine biota.

- Determine potential interventions and recommend options for management of in-river structures that might obstruct movement of riverine biota.
- Investigate novel approaches to identification and management of freshwater dependent biomes within the Swan-Canning river system.

### Progress

- Pools of high ecological integrity were identified in the lower Helena River and water releases negotiated to maintain their viability as refuges over summer months.
- Due to changes in the operations of the water supply dam upstream, effort is now focused on identifying winter and spring water requirements for key biota in the lower Helena River. A trial of water release rates was undertaken to determine habitat connectivity and in collaboration with Murdoch University, fish communities and movement were surveyed.
- Desktop analyses identified more than 200 potential barriers to fish passage between the Kent Street Weir and Canning Dam and initial ground-truthing determined the degree of obstruction to fish movement.
- One barrier was modified to obstruct passage after it was determined introduced fish species were extending their range and potentially threatening vulnerable populations of native fish upstream.

### Management implications

- Monitoring of river conditions, flow data and weather forecasts informs planning of water releases on the Canning and Helena rivers to maximise efficient use of water for ecological benefit.
- Assessments of aquatic communities, including fish, crayfish and freshwater mussels, informs minimum water requirements to protect key ecological values and are utilised by water managers to prescribe appropriate water releases.
- Preliminary assessments of in-stream barriers identified many previously unknown structures, and further work is underway to determine the ecological impacts of the structures. This will enable river management to develop a strategic approach to retaining, modifying or removing the structures to improve ecological connectivity, limit pest species distribution or to reduce liability and risk as asset managers.

### Future directions

- Review historic information and research Helena River values and responses to flow from and develop a discussion paper in consultation with DWER for use in updating water provisions for environmental benefit.
- Impediments to connectivity between critical habitats in the Canning River will need to be addressed. This will require completion of ground-truthing the in-river structures, evaluation of management options and prioritisation of structures for modification to enable the most effective connectivity of critical habitats and protection of vulnerable communities.



### Swan Canning Water Quality Monitoring

SP 2020-027

S Hoeksema, J Baker, S Robinson, P Howie, J Watsham, J Cosgrove, S Thompson, P Novak, K Traylor

### Context

Water quality in the Swan Canning Estuary and its catchment has been routinely monitored over the past twenty five years, producing one of the largest continuous data sets for any estuarine system in Australia. Data produced through the monitoring program provides essential information to assess system response to management actions and changes in estuary condition over time and report against estuary water quality targets, catchment nutrient reduction targets and phytoplankton trigger levels. Data has also been used to progress the development of estuarine and catchment models that contribute to decision support.

## Aims

- Undertake regular monitoring of water quality and biological parameters in the Swan Canning Estuary and its catchment to provide weekly updates and annual reports on the condition of the river system that inform management actions.
- Undertake weekly monitoring of physical water quality parameters and collection of phytoplankton samples and fortnightly collection of nutrient samples at routine estuarine monitoring sites, and fortnightly monitoring of physical water quality parameters and collection of nutrient samples at routine monitoring sites in the catchment.

## Progress

- Weekly water quality profiles were taken at 42 sites and weekly phytoplankton and fortnightly nutrient samples were collected at 21 sites throughout the estuary.
- Processes and methodologies have been continually improved to create efficiencies in process and reporting to management.
- An additional monitoring site was added in the Canning Estuary to better inform management of water quality in the Shelley Bridge area.
- Water quality profile reports were updated weekly on the Eyes on the Swan Canning Riverpark web page.
- Annual reports on water quality, phytoplankton and nutrients for both the estuary and the catchment are available via the website and production of the 2019-20 reports is underway.

## Management implications

- Data collected through the monitoring program is being used to report against objectives of the River Protection Strategy; inform the Estuarine Response Model and the development of an updated Swan Canning Water Quality Improvement Plan catchment model; and help assess the propagation of the *Alexandrium* blooms in the Swan Canning Estuary in 2019 and 2020.

## Future directions

- Continue to develop processes and refine approaches to monitoring, including electronic entry systems for field data.
- Assess water quality data collected in 2019-20 to complete reports on estuarine and catchment condition and contribute to the review of conditions associated with *Alexandrium*.



## Investigations of contaminants in the Swan Canning

SP 2020-026

P Novak, S Hoeksema, K Trayler

## Context

The Swan Canning Estuary is home to diverse faunal assemblages, productive seagrass and macroalgal communities and is a focus for many water-based activities, including recreational fishing. The estuary is situated wholly in the Perth metropolitan region and drains a large agricultural catchment. As such, it faces many anthropogenic stressors including flow reduction, excessive nutrient input, and contaminant loading associated with a range of contemporary and historical land uses. Ensuring environmental and social values are maintained requires an understanding of threats. In particular, it is important to understand the extent, distribution and potential impact of both novel and legacy contaminants, evaluate risk to ecosystem and human health and improve approaches to management.

## Aims

- Determine the distribution, extent and type of contaminants in the surface water and sediment of the Swan Canning Estuary and its catchment.
- Determine the uptake of contaminants in key estuary biota.
- Understand potential risk to human health through consumption of estuarine species.
- Explore potential control mechanisms for contaminants.

## Progress

- PFAS exceeded environmental guideline levels in surface water throughout the Swan Canning Estuary and catchment. Concentrations were highest in the Middle Swan and Canning Estuary reflecting catchment inputs and suggesting groundwater may be moving PFAS contaminants from sources into the Middle Swan Estuary.
- A report determining the distribution extent and likely sources of Perfluoroalkyl and Polyfluoroalkyl substances (PFAS) contamination in the Swan Canning Estuary and catchment, focusing on surface water and two ecological and recreationally important aquatic species, blue swimmer crabs and black bream, has been completed.
- A report determining the concentration and composition of contaminants in western school prawn in the Swan Canning Estuary in order to provide human consumption guidance and baseline data for this species, has been reviewed by external stakeholders.
- A report investigating the change in sediment contamination status in the Swan Canning Estuary is in preparation.
- An investigation to determine the effectiveness of the Ellen Brook Constructed wetland to remove and store PFAS from surface water is underway.

## Management implications

- Information on the distribution and concentration of contaminants in the estuary is used to identify the potential for environmental risk to the estuary.
- Analysis of PFAS in surface water in the estuary indicates low risk.
- Three surface water catchments where PFAS concentrations were elevated have been identified and management activities to mitigate PFAS run off have been initiated.
- Low levels of PFAS concentrations in black bream and blue swimmer crabs, and contaminant concentrations in western school prawns, indicate there is no health risk to recreational fishermen.

## Future directions

- A report on contaminants in sediments of the Swan Canning Estuary will be completed.
- A report on the effectiveness of the Ellen Brook Constructed Wetland to remove PFAS from surface water will be completed.



## Incident investigations, response and advice

CF 2018-095

K Trayler, J Cosgrove, S Hoeksema, S Thompson, P Novak

## Context

Rivers and Estuaries Science plays an important role in investigating issues as they arise in the Swan Canning Riverpark. This involves investigating events (such as harmful algal blooms, fish kills and pollution discharge), examining causes, implications and response actions.

## Aims

- Monitor toxic algal blooms as they arise and report to an incident response team.
- Investigate fish kills as they arise and inform the incident response team.
- Investigate dolphin deaths as they arise, collate information and influence management / operations where required.
- Investigate and provide advice to management on contaminant spills.
- Provide information and advice to support river management and planning.

## Progress

- Three harmful algal blooms in 2019/20 including an *Alexandrium* bloom (December to May) were tracked weekly and algal toxins in biota were tested.
- Analysis of levels of paralytic shellfish toxins (arising from *Alexandrium*) in mussels were up to eleven times the safe human consumption guidelines. Levels in crab (viscera) peaked at twice the guideline levels.
- Analysis of a fish kill in the Canning River showed association with a bloom of the harmful dinoflagellate, *Karlodinium* spp, but low oxygen conditions may have also played a role.
- Analysis of a fish kill in the Freeway wetland, adjacent to the Swan River, showed association with oxygen levels and high densities of *Heterocapsa* spp.
- The deaths of three dolphins in the Riverpark in November 2019 were investigated and are thought to be linked to cetacean morbillivirus.
- A major fire at the Cleanaway facility in South Guildford resulted in firewater runoff into drainage lines. These were monitored and advice provided to clean-up operations.

## Management implications

- Investigation of fish kill events provides information to support incident management and the coordination of agency responses.
- Monitoring of the algal bloom and toxin testing provides information to support Department of Health warnings to the public to avoid fishing in affected areas.
- *Alexandrium* is known to produce cysts that can stay dormant in river sediment. Therefore it is likely that algae will return again when conditions are suitable.

## Future directions

- Response guidelines for harmful algal blooms are revisited annually.
- Refine triggers for algal bloom response, protocols for biota testing and trigger levels for biota toxin response.



## Seagrass monitoring and evaluation

SP 2018-039

J Cosgrove, K Trayler, P Howie, J Watsham, K Murray, S Strydom

## Context

Seagrasses are a highly valued component of estuary ecosystems as they improve water quality by reducing sediment resuspension and removing nutrients as well as providing habitat and a food source for waterbirds. Seagrasses respond to changes in their physical and chemical environment and are recognised as being a bioindicator of ecosystem health, with loss of seagrass representing degraded conditions. Ensuring that seagrass communities remain viable and resilient is an important component of effective estuary management. DBCA is continuing to monitor seagrass throughout the Swan Canning Estuary both to inform management decisions in response to new development proposals and to track the condition of seagrass meadows and estuarine health.

## Aims

- Describe the natural variability of seagrass cover, species composition and other seagrass meadow characteristics as related to changes in key climatic conditions.
- Understand the sensitivity of seagrass metrics in response to anthropogenic stressors such as water quality, sediment stress, drift macroalgae load and invasive species.
- Periodically update seagrass habitat maps.

## Progress

- A semi-validated seagrass habitat map has been produced based on reviews of thousands of benthic images.
- Summer sampling was completed successfully. Effective reproduction was found at most study sites (average number of seeds in fruit per square metre ranged from 43.4-210.4), although the Lucky Bay site (Attadale foreshore) showed no evidence of reproduction (zero seeds or fruit detected).
- An early season die-off event was recorded after an extreme low tide on when the temperature reached 41.6 degrees. This impacted only the shallowest areas that were exposed during the low tide; however, extensive areas were defoliated. Monitoring showed that *Halophila ovalis* recovered relatively quickly from this event but stands of *Ruppia megacarpa* appeared less healthy throughout the season.

## Management implications

- The semi-validated map has been useful both internally and with stakeholders for informing development proposal assessments on other actions in the Swan Canning Riverpark.
- New temperature data has highlighted water temperature variability across sites and the added stress experienced by shallow seagrass meadows, especially when combined with zones of low flow (high water residence time). This will allow prediction of high risk periods for potential seagrass die-off events via ocean level predictions with tide and temperature forecasts, and provides information to support community education and communications to interest groups (e.g. Swan Estuary Reserves Action Group) that alleviate community concern.

## Future directions

- A full review of the sampling and analysis plan is to take place in the first quarter of the 2020-21 financial year.
- The department continues to value add its monitoring program by engaging with university researchers and students.



## Algal blooms: investigations and control

SP 2018-035

K Trayler, J Cosgrove, S Thompson, S Hoeksema

## Context

Parts of the Swan and Canning rivers are affected by algal blooms, with the species effecting blooms varying temporally and spatially. While most algal blooms are harmless, on occasion toxic blooms occur that can be harmful to the rivers, wildlife and humans. The impact of these blooms on environmental and social values will depend on the type and severity of the bloom. Understanding the dynamics of algal blooms is important in determining their impact and approaches to their control. Regular monitoring of the Swan and Canning rivers enables both retrospective analyses of bloom events and adaptive approaches to in-river bloom management. There are many approaches promoted for managing algal blooms. Finding useful and applicable methods for managing blooms in the Swan and Canning rivers requires a combination of desktop analyses, laboratory and field based trials. It is also important to consider the potential impact of control products on waterway values.

## Aims

- To investigate harmful algal blooms and understand factors influencing their presence and toxicity.
- To test the products suitable for controlling algae in laboratory and field settings.
- To understand risk associated with blooms and bloom control products.
- Refine tools that contribute to understanding algal blooms.

## Progress

- A field trial of the 'Water Cleanser' product was undertaken in a freshwater setting. Algal and physico-chemical analyses is complete, with assessment of other factors pending.
- A laboratory trial to determine the effectiveness of bentonite clay at removing *Alexandrium* from the water column was undertaken.

## Management implications

- Results of a laboratory trial suggest that the 'Water Cleanser' was not effective in controlling cyanobacteria.
- There is currently no mechanism available locally to effect immediate control of an *Alexandrium* bloom in the Swan Canning Riverpark.

## Future directions

- Further analyses of the 'Water Cleanser' trial data set to examine changes in algal composition and non-target (zooplankton) effects.
- Further investigation of the *Alexandrium* bloom. An extensive data set of physico-chemical and biotic data has been collected with the view to evaluating factors that drive the presence and toxicity of these blooms.
- Investigation of modified clays for *Alexandrium* control in a laboratory setting.



### Alfred Cove eutrophication investigation: gaining insights to apparent eutrophication-related stress exhibited by seagrass in the Swan Estuary Alfred Cove Marine Park

SP 2018-034

J Cosgrove, K Trayler

## Context

The Alfred Cove Swan Estuary Marine Park (ACSEMP) is a 200 hectare area encompassing mudflats, seagrass meadows and intertidal vegetation, that provides habitats for a variety of animals including internationally important migratory wading birds. Previous seagrass monitoring and evaluation has suggested that seagrass meadows in the Alfred Cove area are in relatively poor condition compared to other areas of the Swan estuary. Seagrasses play an important role in estuaries such as the Swan Canning Riverpark, by providing habitat, acting as a primary food source for black swans and stabilising sediments. Given the ecological services that seagrass meadows provide, it's imperative that we identify and understand drivers behind poor seagrass meadow health.

## Aims

- Determine seagrass nutrient content in Alfred Cove and surrounding areas of the estuary.
- Investigate potential nitrogen sources and degree of eutrophication in Alfred Cove and compare this with seagrasses in surrounding areas of the estuary.
- Understand the roles of elevated eutrophication signals in influencing the productivity of seagrass.
- Investigate heavy metal concentration of seagrass tissue at Alfred Cove and determine if there is a relationship between seagrass standing stock and metal concentration.

## Progress

- Seagrasses at Alfred Cove site (AC3) were in poor condition compared to nearby estuary sites. The identified key stressors included: low water movement (associated high water temperatures and extreme dissolved oxygen levels) and  $^{15}\text{N}$  enrichment and tissue nitrogen concentration. Enriched  $^{15}\text{N}$  values may arise from high levels of  $\text{NH}_4^+$  in groundwater entering the interstitial waters of the rhizosphere.
- An adjacent, slightly deeper site recorded the healthiest seagrass in the estuary with a  $^{15}\text{N}$  value indicating N sources of either plant fertilisers ( $\text{NO}_3^-$  nitrate) or biological N-fixation from associated bacteria.
- Heavy metals were detectable in *H. ovalis* tissue at all sites, and translocated (root to shoot) Zn and Cd may influence health.
- Groundwater is likely the dominant source of nitrogen for seagrasses at Alfred Cove site AC5, and the main source of nitrogen for Alfred Cove sites AC4 and AC3, but unable to verify this due to a lack of groundwater  $^{15}\text{N}$  data for these sites.

## Management implications

- The spatially restricted nature of the seagrass degradation at Alfred Cove highlights the dangers of generalising seagrass health conditions across local scales (kilometres).
- Engagement with the City of Melville regarding management of fertilisers in key areas may address concerns around those sites identified as potentially impacted by fertiliser-laden surface water runoff.
- Further knowledge has been gained on the interactive nature of multiple stressors to seagrass health, including site bathymetry and impact on water residence time. This will inform the design and placement of any future shallow-water structures in the Riverpark that may impact water residence times of nearby areas, and improve the identification of seagrass meadows at higher risk.

## Future directions

- This project is completed.



## Investigating fish communities as an indicator of estuarine condition

SP 2018-033

K Trayler

## Context

Fish communities exhibit predictable responses to ecosystem degradation/stress, and thus may be used as sensitive indicators of the ecological condition of these systems. Biotic indices, based on fish and other biological communities, are now used worldwide to quantify the ecological health of rivers, lakes, estuaries and many other environments. This project applies a Fish Community Index developed by Murdoch University in collaboration with government agencies (2007-2012) as a measure of the condition of the Swan Canning River system. This has been part of regular monitoring and reporting on the waterway since 2012 and a report on fish communities in the Swan Canning Riverpark is released to the public annually.

## Aims

- Undertake the evaluation of the fish communities in the Swan Canning Riverpark for the purposes of applying the fish assemblage based index of estuarine condition and reporting.

## Progress

- Fish communities were sampled at 48 sites and collected fish were identified, counted and returned to the water alive.



- Species abundances in each sample were used to derive values for core metrics including the numbers, diversity and identities of species, and the relative proportions of species with different feeding and habitat requirements. These underpinned the calculation of the nearshore and offshore fish community index and were used to calculate an overall index score for each zone.
- A report and summary paper documenting the 2019 results was released. The report translates index scores to quantify ecological health and results are reported as a conceptually simple letter grade.

### Management implications

- The Fish Community Index considers the fish community as a whole and provides a means to assess how the structure and function of fish communities in shallow nearshore and deeper offshore waters respond to a wide array of stressors affecting the ecosystem.
- In 2019, the shallow nearshore areas and offshore waters of the system were assessed as fair. These results are consistent with the relatively stable trend in condition since 2011.
- The Canning Estuary scored poorly relative to other zones in both seasons. Since the start of regular fish community monitoring in 2012, the offshore waters of this zone have consistently scored poorly relative to those of the other zones across both seasons (receiving a D grade in 50 percent of monitored seasons), and some additional monitoring may be necessary to better understand the factors underlying this trend.

### Future directions

- A report documenting the results of the 2020 sampling will be completed.
- Increased monitoring of water quality in the Canning Estuary to better understand factors affecting fish communities in this zone.



### Explaining foreshore vegetation die-off

SP 2018-030

K Trayler, B Huntley, A Okum

### Context

At key locations in the Swan Canning Riverpark there is evidence of riparian decline. At Guildford, widespread die-off of *Eucalyptus rudis* (flooded gum) has occurred and *Phytophthora* pathogens are suspected to play a role. However, this is a complex issue and a range of adverse environmental changes can influence the disease. There is potential to link LiDAR data, vegetation survey, information on plant water requirements, salinity tolerance and hydrodynamics in order to better understand the vegetation decline. The Swan Canning Estuary Response Model, housed at UWA, will be used for this purpose. An associated study being undertaken by Murdoch University is exploring pathogen presence and soil influence on vegetation decline at Guildford. Together these investigations will work to understand what may be causing the decline in vegetation in that area.

### Aims

- Use remote sensing to identify and map historic vegetation condition change.
- Combine field survey and model development to determine to what extent hydrodynamic changes (inundation extent, period and salinity) have contributed to the vegetation decline at agreed locations in the Swan-Canning Riverpark.
- Investigate tree health by examining leaf nutrients, pathogen presence, soil moisture, nutrients and mycorrhiza.
- Trial phosphite injection and nutrient implants as treatment option to combat *Phytophthora* for affected flooded gum in the Guildford area.
- Predict where future change is likely to create heightened risk of tree decline, and make recommendations for remediation and revegetation approaches, and future research.

## Progress

- Groundwater salinities were high (approximately one-third of seawater) driven by accumulation of surface salts following high water events (greater than 1m AHD), and via subterranean movement of river water into the floodplain aquifer (summer/autumn).
- The Swan Canning Estuary Response Model was linked with LiDAR data to provide a domain that extended into the riparian zone and enabled simulation of water levels, inundation and salinity. This enabled creation of local and regional habitat-salinity risk maps for 2008-2018 and a drier climate for 2050.
- The phosphite injection and nutrient implant trial involved community participation. At the Helena confluence in Guildford, 120 trees, divided into 30 groups of four trees were treated either with phosphite; nutrient implant (Phoscap®), phosphite or Phoscap® combined; or left untreated.
- None of the treatments were effective and did not result in significant health responses in the tree canopies, as determined by three health measures, over the 12 months of monitoring.

## Management implications

- The model provides an exploratory tool to view the sensitivity of riparian zones under forecast hydrodynamic conditions. Low lying, poorly drained areas between Bayswater and Guildford are at greatest risk of tree decline under hydrodynamic projections.
- Site scale appraisal of drainage and surface water to enhance freshwater flushing and / or groundwater freshening may be required to address salinity in areas where flooded gum are at high risk. Where this is not possible, revegetation approaches should focus on salt tolerant species.
- Salinity intrusion into the Helena confluence area may be making flooded gums more susceptible to *Phytophthora* and rendering treatment approaches ineffective. Flooded gum revegetation should be focussed in low to moderate risk areas.

## Future directions

- This study is complete.



## Application of FlowCAM® to biological monitoring in the Swan Canning Riverpark

SP 2018-029

J Cosgrove, K Trayler

## Context

The department conducts weekly water quality monitoring of the Swan Canning Riverpark. Water-borne microscopic algae (microalgae or phytoplankton) are a key biological component of the estuarine ecology and have been counted and characterised by taxonomists since the inception of the monitoring program in 1994. Both monitoring technologies and data requirements have evolved since then and this project explores the potential of imaging flow cytometer technology to augment plankton monitoring in the Swan Canning Riverpark.

## Aims

- Assess the use of a FlowCAM® imaging flow-cytometer in estuarine waters and compare results to traditional monitoring data.
- Highlight any additional data streams (e.g. zooplankton data, biovolume data) provided by the FlowCAM® and the quality of these data.
- Consolidate findings into management focussed recommendations for phytoplankton monitoring in the Swan Canning Riverpark.

## Progress

- Analysis suggests that accuracy of the FlowCAM® is poor when samples are from relatively turbid estuarine waters and preserved with Lugols iodine solution (preventing use of chlorophyll fluorescence triggered

mode). FlowCAM® could be used in a targeted fashion to provide important cell metric information and permanent visual record (images) of phytoplankton encountered in the Swan Canning Riverpark.

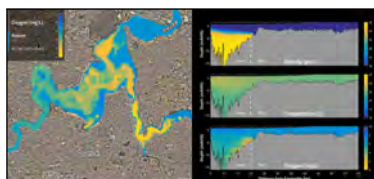
- A report on the project was produced.

### Management implications

- FlowCAM®-VS with current autclassification software is not appropriate for phytoplankton count and identification within the Swan Canning Riverpark monitoring framework.
- Technologies such as the FlowCAM® imaging flowcytometer may provide other useful data streams such as cell biovolume estimates.

### Future directions

- Project is complete.



## Model frameworks for estuarine reporting

SP 2018-027

K Trayler, J Cosgrove, S Hoeksema

### Context

In the period spanning 2011-2016, the department and project partners at The University of Western Australia and Department of Water and Environmental Regulation have resourced the development of a spatially resolved coupled hydrodynamic-biogeochemical model, the Swan Canning Estuarine Response Model (SCERM). The model is a useful tool that can be used for predictive purposes as well as display. The SCERM model has the capacity to complement, but not replace, regular water quality monitoring and to simulate and display information on a wider spatial scale and over finer temporal resolution than the existing weekly water quality reporting. This project explores the capacity of a predictive model framework to rationalise water quality monitoring data, display information in a near real-time format and enhance investigative understanding of the waterway.

### Aims

- Evaluate optimal water quality data requirements for predictive modelling of estuarine conditions.
- Develop a display showing near real-time data.
- Validate model forecast and hindcast.
- Apply model to enhance investigative understanding of estuarine dynamics.

### Progress

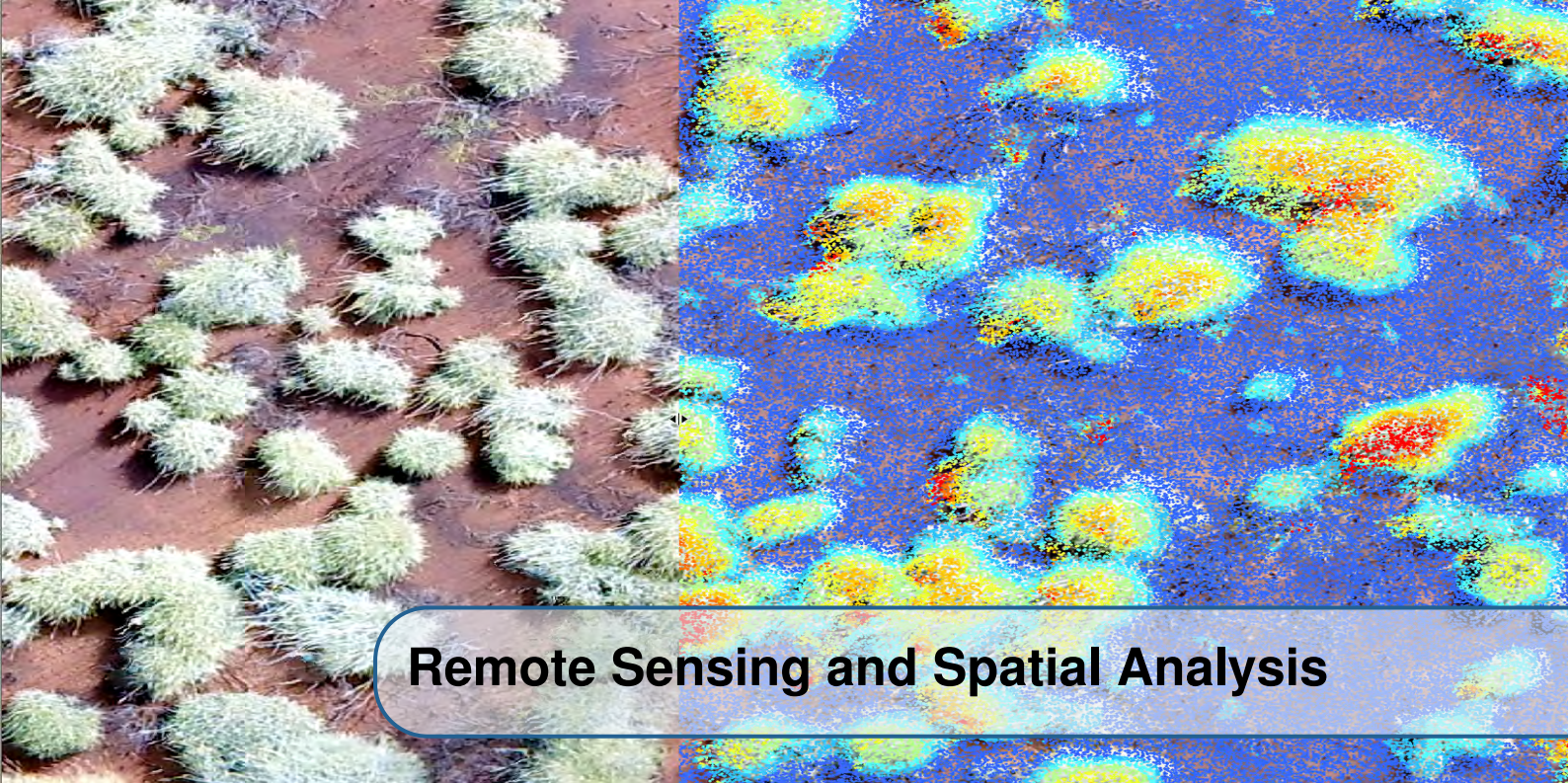
- SCERM v3 has been hindcast against all water quality data 2008-2019 and the metabolism function has been validated by comparing the 2018 simulation against high-frequency data.
- Work commenced to match model outputs of physico-chemical conditions to biotic data sets.

### Management implications

- Model accuracy is important in determining the level of confidence that can be placed in predictions. SCERM accurately reproduced physical conditions (salinity and temperature) of the estuary system, and effectively captured variations in dissolved oxygen and some of the nutrient pools. Reasonable accuracy was also obtained for other nutrient pools and chlorophyll *a*.
- The model is now suitable for assessing management scenarios associated with artificial oxygenation, nutrient and load management and/or climate change, bearing in mind some deficiencies that have been highlighted. Thus it is an important decision support tool for management of the waterway.

### Future directions

- Utilise hindcast model outputs to correlate water quality and biological information on key populations / communities. Validate forecast conditions in display portal.

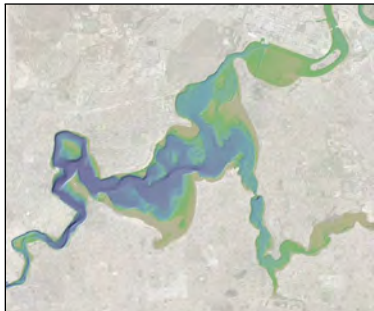


## Remote Sensing and Spatial Analysis

**Program Leader: Katherine Zdunic** The Remote Sensing and Spatial Analysis Program seeks to integrate the science and application of remote sensing and spatial analysis into departmental programs. For a department that manages large tracts of terrestrial and marine conservation parks and reserves, the efficient use and analysis of spatial data is crucial for the understanding of natural processes and to inform management actions.

In recent times the availability of spatial data has increased dramatically. With this increase in data, the Program is continuing to develop sophisticated statistical analysis, interpretative and automation techniques to synthesise this data into a form where it directly assists departmental staff.

The program undertakes fire mapping over extensive areas of the state and has established monitoring programs in the forest, wetland, marine, coastal, rangeland and tropical savanna environments. Species and habitat modelling and spatially explicit assessments, such as risk assessments, allow managers to identify areas of concern and efficiently utilise resources. Program scientists collaborate with other parts of the department, universities, CSIRO, natural resource management groups, resource companies and other research providers.



### Spatial data management

CF 2018-075

J Chapman, B Huntley, J Kinloch, G Loewenthal, K Murray, G Pitt, P Rampant, R Van Dongen, K Zdunic

### Context

This core function manages spatial data sets by creating metadata, cleaning the data to a corporate standard and saving or migrating data in a secure and accessible corporate data repository - the Spatial Data Library. Many of the data sets in the Spatial Data Library are identified through departmental project requirements. Large data sets include imagery and digital elevation models captured for general use across the department or for specific projects and have multiple uses such as time series analysis, spatial analysis, modelling, and decision making for management, monitoring, planning and policy. Departmental collaborations also produce key data sets that are important but may not be ready to use or need a license arrangement in place to be utilised by the department. Making fundamental data sets accessible to all staff through corporate GIS software is an effective way of communicating what science is being undertaken and also assists with determining management priorities and actions.

## Aims

- Identify and manage fundamental data sets created internally and externally that have value to the department and have multiple uses.
- Collate, clean and metadata final spatial data sets developed by science and science collaborations, and migrate this data into Corporate GIS applications and the Spatial Data Library.

## Progress

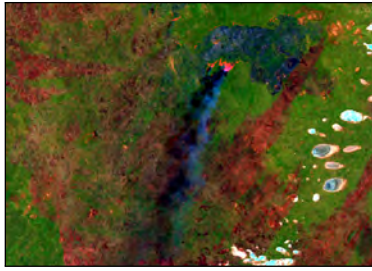
- A copy of the spatial corporate data for the coastal Kimberley region including: aerial and satellite imagery and marine data sets, including resulting data sets from Western Australian Marine Science Institute (WAMSI) were supplied to the marine vessel *Worndoom* to assist with operations, navigation and research trips. Positive feedback was received from DBCA staff on the first trip with the data, where they were able to navigate through uncharted waters with imagery provided and set up two new anchorages and adjust patrol routes.
- The Terrain data set (DEM/LiDAR) Index was updated to include new data sets available to the department on corporate systems.
- Software and scripts were implemented to enable access and process satellite imagery maintained on the National Computing Infrastructure.
- Provided feedback to Department of Transport to enable sharing of bathymetry lidar data captured by the Commonwealth.
- Three bathymetry data loggers were purchased to install on three Kimberley vessels to contribute data to a crowd sourcing bathymetry program run by Geoscience Australia's AusSeabed program to assist with improving coastal bathymetry in the Kimberley.

## Management implications

- Appropriate access and curation of corporate data and imagery means that staff, particularly Kimberley Marine Park coordinators and rangers, are now able to use this data and knowledge to support management, operations and monitoring in Kimberley Marine Parks.
- Feedback to other state agencies, with regards to departmental requirements for high resolution imagery and bathymetry (respectively), is important to ensure future fundamental data sets provided to DBCA fill geographical or temporal gaps, are relevant, and can inform staff adequately to assist with our operational, monitoring, research and management needs.
- Continued development and migration of user-friendly spatial data sets will support the department's need to improve the discoverability and accessibility of science data for all staff.
- Improved coastal bathymetry will assist DBCA regional staff in navigation, management and monitoring operations in Kimberley Marine Parks waters.
- Access to the National Computing Infrastructure leverages super computing resources for departmental requirements.

## Future directions

- Identify terrestrial and marine spatial data sets of corporate value to be migrated to the Corporate Data menu.
- Facilitate the delivery of web mapping service for Land Monitor products to the Corporate Data menu in ArcGIS and QGIS.
- Continue to update satellite imagery, LiDAR and DEM catalogues.
- Continue to develop scripts and functions to utilise satellite imagery on the National Computer Infrastructure
- Install NMEA smartlog loggers on Kimberley vessels and supply bathymetry data to Geoscience Australia's AusSeabed program to improving coastal bathymetry in the Kimberley and feed updated bathymetry models back to the Kimberley.



## Remote sensing and spatial analysis for fire management

CF 2018-074

J Chapman, P Rampant, K Zdunic, J Ruscalleda Alvarez, R Van Dongen

### Context

The department's fire management, monitoring and reporting functions require knowledge of fire events that are effectively derived through fire scar mapping. The imagery used for this analysis is predominantly satellite imagery but also includes optical and thermal imagery from airborne platforms. Research areas include historical mapping that utilise the extensive archive record of satellite imagery and occasionally aerial imagery to build a fire history (or fuel age) for a location or to reconstruct the spread for major bushfire. This activity also includes monthly mapping during the prescribed burn season. The project also plays a key role in fire research and development, through research into fuel growth, fire spread and fire risk models. Internal and collaborative activities are carried out to further streamline and automate mapping techniques. General imagery support is also provided to Fire Management Services Branch and Regional staff. This includes roles such as incident mapping and predictions as required and advice in imagery and systems development.

### Aims

- Improve processes of fire scar identification to enable historical fire regimes to be understood for safety and ecological applications.
- Improve burn security through the development of methodology to detect and communicate hotspot locations.
- Develop techniques to provide inputs for fire behaviour models to enable desktop assessments.
- Provide remotely-sensed spatial and temporal data streams to assist with bushfire investigations and reporting.

### Progress

- Fire scar information for the Pilbara region, Goldfields region, Kanyirninpa Jukurrpa and Desert Support Services was supplied on a monthly and annual basis to inform and report on prescribed burning activities in the Western Desert and Pilbara region.
- Collaborative project with the Great Victoria Desert Biodiversity Trust resulted in fire history and analysis over the Great Victoria Desert over the years 1995 to 2019.
- Support was provided for the operational use of thermal camera to detect hotspots for burn security.
- Provided data to Fire Management Services Branch to inform fire recovery, fire chronology and new satellite technology/availability.
- Training in fire chronology was undertaken.
- Development of processing scripts in R to effectively process the DBCA fire history data.
- A journal article describing the relationship between spinifex fuel cover measured by remote piloted aircraft imagery and Landsat satellite imagery has been published in the *International Journal of Remote Sensing*.

### Management implications

- The information provided for fire management is designed to significantly increase the accuracy of reporting and decrease the risks of fire management activities. Delivering fire scar mapping and information allows practitioners to make informed decisions that lead to more efficient fuel reduction activities and successful completion of burn prescriptions.
- Effectively processing the DBCA fire history provides quantitative and current statistics on fire frequency, number of repeat fires and fire interval.
- Developments in remotely piloted vehicle application together with satellite imagery will enable fire managers to more efficiently and accurately map fuel characteristics at a range of scales, greatly enhancing their ability to forecast fire danger and to predict fire behaviour without having to carry out costly ground-based field measurements.

- Consistent production and attribution of monthly fire scar mapping has resulted in the compilation of an annual fire scar mapping product with improved date, area and cause attribution. This product is suitable to analyse and provide spatial metrics that will aid in assessing the effectiveness of the fire management program over Millstream Chichester and Karijini National Parks.
- Security of burns is improved by the delivery of thermal imagery hotspots to on-ground staff.

### Future directions

- Continued development and automation of fire scar detection methodology.
- Investigation and development of new data sources including new satellite data and aerial capture.
- Implementation and development of the spatial analysis of fire patterns and fuel loads.
- Further development of spinifex fuel cover from satellite imagery with greater field data inputs across the State.



### Spatial analysis and modelling

SP 2018-073

J Kinloch, K Zdunic, G Loewenthal, G Pitt

### Context

The spatial analysis and modelling project develops and utilises tools to assist in the evaluation, interpretation and prediction of conservation values, threatening processes and management actions. These tools generally integrate spatial data sets, expert knowledge and GIS modelling techniques to produce spatially explicit products that can be used to inform decision-making. Projects can be focused on species occurrence (e.g. species distribution models, habitat suitability modelling), animal movement (e.g. home range, identification of habitat linkages), landscape scale processes (e.g. assessment of habitat fragmentation) or assessments such as quantifying risk (e.g. risk presented by feral cattle to biodiversity values). Identification of areas of high conservation value for protection are also undertaken through combining numerous conservation value data sets and using software to evaluate possible conservation scenarios.

### Aims

- Develop spatial models to describe ecological processes, thereby increasing the understanding and protection of biodiversity.
- Undertake spatial analysis tools to inform management and support decision making.
- Collate and summarise spatial information using statistical and documented methods to inform monitoring and management practices.

### Progress

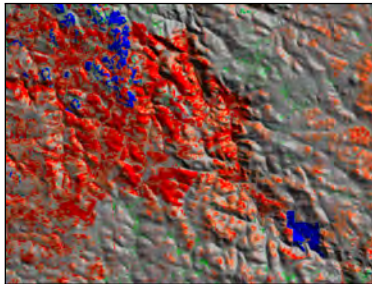
- A consultative review of the Comprehensive, Adequate and Representative (CAR) reserve analyses was undertaken.
- Report completed on the satellite tracking and spatial metrics of horse movement on the Fortescue Marsh and Upper Fortescue Catchment.
- Development of spatial metrics describing threatened and priority flora and threatening processes.
- Multi criteria analysis undertaken to aid the assignation of ecological value to the wetlands of the Swan Coastal Plain.
- Utilised Urban Monitor data and object based image classification to produce variables which were then used to model land use in the Swan and Canning catchments.
- IVEST risk assessment undertaken for north west shelf turtle conservation.
- Investigation of micro climate models in the Pilbara using ibutton climate data.

## Management implications

- Information on feral herbivore hotspots and feral animal movement will inform the annual removal programs on the Martu Determination Lands and the development of feral herbivore management strategies for the Fortescue Marsh.
- CAR analyses review streamlines reporting and deliverables relevant to DBCA and the Department of Water and Environmental Regulation.
- Multi criteria analysis of the ecological value of wetlands is providing a transparent and repeatable method to communicate and deliver information to aid planning and development.
- Land use modelling outputs are being used to model nutrient flows into the Swan and Canning rivers.
- Spatial metrics of threat aid the evaluation of the vulnerability of threatened and priority flora to threatening processes.

## Future directions

- Undertake further spatial modelling to support the planning of feral herbivore programs.
- Produce and publish 2020 vegetation statistics reports.
- Work on standard methods and metrics to discriminate Tuart woodland and forest areas using Urban Monitor products.
- Continue to provide advice on the development of species distribution models for threatened and priority species and develop models when appropriate.
- Apply developed multi criteria evaluation of the ecological value of wetlands to the south-west and Moora west regions.
- Spatial analyses and support for the identification of conservation freehold purchase.



## Remote sensing monitoring

SP 2018-072

J Chapman, B Huntley, G Loewenthal, K Murray, G Pitt, P Rampant, R Van Dongen, K Zdunic

## Context

The measurement and analysis of change across terrestrial, wetland and marine environments using remote sensing provides essential historical and current information that can be used to understand the effects of management actions and natural events. The imagery used is predominantly satellite imagery, but also includes optical imagery from handheld and airborne platforms and LiDAR data. Field observations provide essential ground truth and calibration of remotely sensed data. Analysis techniques include an increasing number of sophisticated time series analysis tools and object orientated image classification. This work is underpinned by efficient and statistically rigorous analysis and batch processing techniques in the R programming environment. This function relies on repeatable and consistent source imagery and developing methods to produce reliable spatial and statistical products that can be used by the department for reporting on the state of the environment, managing the conservation estate and assessing threats to biodiversity.

## Aims

- Undertake remote sensing monitoring and research projects at a range of temporal and spatial scales using technologies which include satellite imagery, digital cameras, remotely piloted aircraft and LiDAR data.

## Progress

- A system to assess plantation stocking rates for Forest Management Branch was implemented and stocking rates over 120 plantations were assessed.
- A draft paper on monitoring revegetation of *Banksia* woodlands using satellite imagery has been prepared.



- Vegetation cover change maps over 194 covenants in the south-west were created. The maps identify areas of cover loss between the registration date and 2020.
- Analysis of vegetation cover change identified in the Forest Management Plan was carried out. The analysis focused on the northern third of the northern jarrah forest and investigated at changes in rainfall, fire intervals and the effects of thinning.
- The Millstream Chichester National Park riparian vegetation monitoring was continued.
- Input was provided to the Land Monitor project to develop satellite based rangeland vegetation monitoring.
- Imagery report on suspected illegal clearing for the Department of Water and Environmental Regulation was completed.
- A report on the vegetation cover change in the 'Koolanooka System' threatened ecological community was prepared.
- Identification of pine wilding density in the Gngangara region using digital aerial photography products from the Urban Monitor project continued.
- Remote piloted aircraft (RPA) captured 79 mangrove field sites in the proposed Dampier Marine Park area for development of satellite derived mangrove vegetation cover and monitoring products.
- RPA captured field sites for proposed Dampier Marine Park and North Kimberley Marine Park have been processed to provide vegetation cover metrics. These metrics have been used to develop regional mangrove time-series products using Analysis Ready Sentinel 2 Satellite Imagery for the Pilbara and Kimberley Regions.
- Shark Bay seagrass extent mapping was extended to the World Heritage Area for 2002, 2010, 2014 and 2016 and completed. Analysis of the seagrass extent was conducted in relation to sea surface temperature and the marine heatwave of 2011. This work has now been published in *Global Change Biology*.
- Wetland inundation and hydroperiod analysis for various wetlands throughout the state was undertaken utilising satellite imagery.

### Management implications

- The pine wilding mapping is required to ensure a pre-determined stocking rate is maintained. This stocking rate has implications on food availability and population viability of the Carnaby's black cockatoo.
- Stocking rate assessments for Forest Management Branch provide a cost effective and comprehensive process to assess stocking rates in plantations.
- The vegetation monitoring paper outlines cost effective methods to monitor and assess completion criteria of revegetation projects.
- The Forest Management Plan vegetation change analysis provides information on the potential impacts of climate change and the sustainable use of our forests.
- The improvements made to the mangrove extent, density and trend timeseries products using RPAs and Analysis Ready Data has provided more reliable, realistic and robust timeseries products for the Pilbara and Kimberley Regions, that will make future timeseries updates quick deliver.
- Comprehensive information on the dynamics of seagrass extent in response to marine heat waves in the Shark Bay World Heritage area will inform management responses to the loss of habitat.
- Wetland inundation and hydroperiod analysis provides information to understand the status and conservation significance of wetlands especially those remotely located.

### Future directions

- Improve the plantation stocking rate assessment system to handle plantation variability and move to the assessment of native forests.
- Complete assessment of covenants using imagery from the registration date to 2020 and implement an analysis from 2016 to 2021 using higher resolution imagery.
- Expand Forest Management Plan cover change analysis from north eastern jarrah forest to Collie region.
- Continue to explore and develop cloud processing options with Geoscience Australia.
- Complete pine wilding mapping and develop a repeatable monitoring system.
- Develop and refine the use of remotely piloted aircraft imagery for vegetation monitoring and mapping.
- Further develop mangrove monitoring methodology through RPA validation to test the accuracy of the products and incorporating recent advances satellite imagery calibration.
- Package the Shark Bay seagrass data sets and associated habitat mapping, and R scripts for creating sea surface temperature metrics, and make publicly available.



## Dirk Hartog Island vegetation monitoring

SP 2018-009

R Van Dongen

### Context

In 2009, Dirk Hartog Island (DHI) was gazetted as a National Park and the process to remove introduced animals and reintroduce native mammals began. A vegetation monitoring program was developed that integrates detailed floristic surveys, repeated site photography and Landsat satellite imagery to provide a comprehensive picture of vegetation condition and how the island's ecology has changed since destocking.

### Aims

- Monitor changes in the native vegetation cover following destocking of introduced herbivores.
- Monitor native vegetation cover changes with the recent reintroduction of native fauna.

### Progress

- Analysis of remotely piloted aircraft imagery captured over fauna exclusion plots was undertaken. The aim of this work was to determine the potential of this imagery for mapping plant species for reporting purposes.
- A draft manuscript on the feasibility of using remotely piloted aircraft imagery to estimate plant species has been prepared.
- Vegetation cover change across the island was analysed with 39 percent experiencing a significant increase since destocking.
- The area of sand dune on the island has dramatically decreased by approximately 833 hectares in the period 2009 to 2020.

### Management implications

- Results from the program demonstrate the benefit of the eradication program and provide management with evidence that, with the improvement in vegetation condition, the mammal reintroduction program has the best chance of success.
- The data collected and study of the fauna exclusion plots will help measure the impact of the reintroduced fauna.

### Future directions

- Update the vegetation monitoring using Landsat imagery and carry out field validation of vegetation change.
- Update the sand dune area movement.
- Explore how the current vegetation monitoring method can be integrated into the TERN system.



## Species and Communities

**Program Leader: Ruth Harvey** Species and Communities Program supports the delivery of the *Conserving Habitats, Species and Ecological Communities Service* through the provision of consistent and reliable products, information and advice regarding: legislation development and interpretation; policy development and interpretation; planning and setting priorities; implementing biodiversity conservation programs; maintenance of data and other information; and community engagement.

The program supports the department's operations in the areas of: threatened fauna, flora and ecological communities conservation; fauna and flora management; wetlands conservation; administering the departmental Animal Ethics Committee; and off-reserve conservation.



### Wetland conservation

CF 2018-067

M Coote, F Felton, C Harding

### Context

Wetland conservation activities are conducted to improve the identification, protection, knowledge and management of wetlands on the conservation estate and off-reserve across Western Australia. The department partners with the Australian Government in implementing responsibilities under the Ramsar Convention of Wetlands to coordinate the protection and management of the listed sites in Western Australia and assist in delivery of the Ramsar goal of the 'Wise Use of all wetlands' in the State. Maintaining wetland inventory across the State allows the department to provide accurate technical and scientific advice on values and impacts to high ecological value wetlands to decision makers in land use planning and environmental impact assessment processes. Many high ecological value wetlands are located on private property and the Healthy Wetland Habitats program provides an incentive for landowners to conserve and improve their wetlands.

### Aims

- Coordinate the partnership responsibilities with the Australian Government for the implementation of the Ramsar Convention in Western Australia.
- Assist development of strategic policy for the conservation of high ecological value wetlands.
- Provide strategic technical advice in environmental impact assessment and land use planning processes for the protection of wetlands within the State's conservation reserve network and other high ecological value wetlands.

- Implement the off-reserve program for the conservation of high ecological value wetlands on privately owned land on the Swan Coastal Plain.
- Maintain the wetland mapping data sets for which the department is the custodian.

### Progress

- A new wetland mapping data set has been developed and an evaluation data set for the Swan Coastal Plain analysed. The data set has been distributed to stakeholder groups for comment.
- Contributed to an assessment of the Muir-Byenup System Ramsar site, as a case study in the development of a national framework for assessing climate change vulnerability of Ramsar listed wetlands in Australia.
- Contributed to a workshop to develop a Climate Change Response Strategy for the Muir-Byenup System Ramsar site.
- Review of the ecological character description and limits of acceptable change was progressed for the Peel-Yalgorup Ramsar site.
- Eight requests to modify the *Geomorphic Wetlands Swan Coastal Plain* data set were processed.
- Contributed to development of the draft Wetlands Buffer Guideline as part of State Planning Policy 2.9.
- Technical advice was provided to departmental staff, other state and commonwealth agencies, land owners and their consultants for 54 land use planning issues.
- The Healthy Wetland Habitats program continued to assist 13 landholders to manage conservation value wetlands on their properties. Five landholders have completed works within voluntary management agreements in 2019/20 which has brought the accumulated outputs of the program to 45.7 km of fencing, 47.2 hectares of weed control and 4.43 hectares of revegetation with 13,307 plants.

### Management implications

- The production of information sheets, mapping and condition reports for Ramsar wetlands will facilitate their ongoing management, and is a requirement for the Australian Government and the Ramsar Secretariat.
- The development of a climate change adaptation checklist for the Muir-Byenup System Ramsar site will facilitate a response strategy to major impacts of climate change.
- Management advice will provide for the protection and management of wetlands.
- Ongoing involvement of private land managers in the Healthy Wetland Habitats program promotes positive management of wetlands.
- Revised wetland mapping will facilitate targeted buffer guidance to be included with *State Planning Policy 2.9*.

### Future directions

- Review and maintain wetland mapping for Western Australia in order to identify high ecological value wetlands for consideration for acquisition into the reserve estate and to inform impact assessment decisions.
- Prepare documentation for reporting responsibilities for the 12 sites listed under the International Ramsar Convention on Wetlands
- Condition survey for Lake Carnegie will be finalised.
- Technical advice on wetland values will continue to be provided using current wetland mapping information for impact assessment from clearing, mining and other development applications.



### Ecological communities conservation and recovery

CF 2018-066

V English, C Harding, R Luu, S Martin, K Nilsson, J Pryde, P Robertson

## Context

The ecological communities team collates and manages biodiversity information, and provides a range of science-based support and advice for the management, protection and recovery of threatened ecological communities (TECs) and priority ecological communities (PECs). Maintaining and managing the TEC database enables the department to provide accurate technical and scientific advice on the protection and management of ecological communities to decision makers in land use planning and environmental impact assessment processes. Undertaking conservation status assessments, including nominations for listing/delisting and changes of status, ensures that the most recent ecological information is available to stakeholders. The team facilitates the Western Australian Threatened Ecological Communities Scientific Committee (TECSC) and coordinates recovery programs, including developing interim recovery plans and supporting recovery teams, to guide conservation activities for TECs and PECs.

## Aims

- Provide evidence-based advice for the management, protection and recovery of TECs and PECs.
- Collate, manage and interpret information on the distribution, conservation status and recovery of TECs and PECs, and deliver a data provision service to ensure data are available within and outside of the department.
- Contribute to the assessment of environmental impact on TEC and PEC conservation values for development and vegetation clearing proposals in accordance with relevant policy and legislation.
- Undertake on-ground assessments to support conservation management and advice for environmental impact assessments and land use planning proposals affecting TECs and PECs.
- Guide strategic and coordinated recovery programs for TECs, including the preparation of recovery plans.
- Undertake assessments of conservation status based on all available data and prepare nominations for TECs and PECs for consideration by the TECSC.
- Implement the sections of the *Biodiversity Conservation Act 2016* (BC Act) that relate to TECs.

## Progress

- As at 30 June 2020, there were 65 extant ecological communities listed under the Western Australian Minister Environmentally Sensitive Areas list in policy (20 critically endangered, 17 endangered and 28 vulnerable), and four listed as collapsed. Another 391 ecological communities were on the PEC list.
- Public consultation was completed for a draft interim recovery plan for a TEC and PEC.
- Interim recovery plans were drafted for three TECs.
- Two meetings of the TECSC were held and Ministerial Guideline 4 was revised.
- The level of threat to 65 ecological communities was assessed against IUCN ranking criteria in preparation for consideration for listing under the BC Act.
- New occurrence information was added and edits to existing spatial information on the TEC and PEC database completed for 1,790 occurrences distributed across the state.
- On-ground survey was undertaken for 28 occurrences of TECs and PECs in the south-west of the State to support conservation decision making.
- Forty two TEC fact sheets including description, indigenous interests and threatening processes were prepared and placed on the department's website.
- Support and specialist input were provided, and meetings attended, for the Threatened Flora and Ecological Communities Recovery Teams in the Swan and Warren Regions, the Albany, Esperance, Central Wheatbelt and Geraldton Districts, and the Sedgeland in Holocene dune swales and thrombolites of Lake Richmond recovery teams.
- Environmental impact assessment advice was provided in relation to 103 clearing permit applications, land use planning, mining and development proposals.
- Eleven assessments for applications to modify a TEC in anticipation of listing under the BC Act were completed and proponents notified of preliminary outcomes.
- Three hundred and ninety-five data search requests for TECs and PECs were processed for a range of stakeholders. Specialist TEC advice was also provided with a number of these requests.
- A report about biological survey and mapping of selected organic mound springs TECs and PECs of the Kimberley Region was completed.
- Two reports recommending TEC or PEC areas for purchase were completed and supported acquisition of 384 hectares of land in the Swan and South West Regions containing two Western Australian and one federally listed TEC for conservation.

- Instruction and training were provided to 11 University of Western Australia Master of Biological Science students and resulted in evaluation and improved mapping of six areas of a Banksia woodlands TEC.
- Detailed technical information and advice were provided about TECs and PECs to support proposed boundaries for 23 new reserves proposed under Plan for our Parks proposals.
- Versions of the proposed web-based Threatened Species and Communities database (TSC) were tested, reviewed and advice provided about its capabilities, structure and content.

### Management implications

- Enhanced data sets for TECs and PECs facilitate improved environmental impact assessments, land use planning, and conservation management.
- Maintenance of up to date data on the TEC and PEC database assists in resolving the threat status of ecological communities.
- Recovery plans and management advice, assist the department and other land managers in maintaining the conservation values of TECs and PECs.
- TEC and PEC data and advice support determinations of priority areas for reservation.

### Future directions

- Continue to provide data and advice for the protection, conservation and management of TECs and PECs.
- Continue to review and provide advice about the proposed TSC database so that it becomes fit for purpose.
- Continue to improve TEC and PEC data.
- Continue to facilitate the TECSC.
- Prepare 23 TEC fact sheets including description, indigenous interests and threatening processes and place on the department's website.
- Undertake public consultation processes for listing of up to 65 TECs under the BC Act.
- Prepare nominations for the TECSC for high priority ecological communities.
- Complete three draft TEC interim recovery plans.
- Publish one interim recovery plan in the Western Australian Government Gazette.
- Continue to develop standard procedures and thresholds for 'modification' of TECs, and process applications to modify TECs under the BC Act.
- Provide letters to owners and managers of private and public lands to notify them of their responsibilities under the BC Act regarding TECs on their land.



### Off-reserve conservation

CF 2018-061

M Hunter, C Kemp, G Stack, L Zhang

### Context

The department supports off-reserve programs to complement its conservation and management of the reserve system. The Nature Conservation Covenant program establishes covenants on land titles to formally protect the land's biodiversity conservation values. Technical and scientific advice is provided through the preparation of management guidelines, and funding is available for voluntary covenants. The Land for Wildlife program is a voluntary, non-binding scheme that provides technical and scientific advice for registered land managers to assist in managing their land for biodiversity conservation. The program is being delivered through a partnership with the Natural Resource Management (NRM) Western Australia regional organisations. The Roadside Conservation Committee has membership from other government agencies, road and rail managers, utility providers and community conservation organisations. An executive officer supports the committee and prepares technical and scientific advice for promoting road and railside vegetation, and promotes this through training programs and consultation. These programs work with other land managers and the community to assist in delivering biodiversity conservation outcomes on lands not managed by the department.

## Aims

- Administer the Nature Conservation Covenant program for both conditional and voluntary covenant programs.
- Increase community awareness of biodiversity conservation and promote the department's biodiversity conservation activities through Land for Wildlife.
- Integrate science knowledge into technical biodiversity management advice.
- Improved conservation management on lands not managed primarily for nature conservation.

## Progress

- Forty four landowners applied for registration with Land for Wildlife during 2019/20, and a total of 1,960 properties are currently registered, supporting 1,145,329 hectares of bushland managed for conservation.
- Nine property assessments were undertaken for Land for Wildlife (LFW) by NRM partners, and seven by the departmental coordinator during the year. Twelve properties were added to the program as members and four were deemed unsuitable.
- Funding was obtained by the Peel-Harvey Catchment Council for the development of an online data management system, and all partners collaborated during its development. This is now live, and all web registrations go through this spatially-enabled portal. All seven NRM partners have access to his data management system, and record member and assessment information there.
- Progress was made on integrating LFW's spatial and non-spatial data sets.
- There were 42 inquiries received from landholders regarding conservation covenants, which led to 18 currently being negotiated.
- Advice was provided to land owners, local government and departmental planning staff on land use planning matters relating to covenants.
- Collaboration was progressed with NTWA and DPIRD to update joint publicity material, and represent the conservation covenant programs of the State at a NRM conference.
- Two meetings of the Roadside Conservation Committee were held.

## Management implications

- Off-reserve conservation plays an important role in achieving the conservation of the State's biodiversity. For example, 68 percent of threatened flora subpopulations (at 2017) occur on land not managed by the department, and 23 percent occur specifically on road and rail reserves. The encouragement of off-reserve conservation actions and the provision of technical support to enable effective management is important for achieving the biodiversity conservation objectives of the department and the State.
- Covenants provide long term protection for biodiversity values on private land.

## Future directions

- Finalise a Biodiversity Conservation Covenant and associated compliance policy, for administration under the *Biodiversity Conservation Act 2016*.
- Continue to administer conditional and voluntary covenants.
- Continue to administer Land for Wildlife.



## Flora conservation and recovery

CF 2018-057

M Smith, C Bourke, T Llorens, J Donaldson, B Richards, J Jackson

## Context

The flora conservation team collates and manages biodiversity information and provides a range of science based support for flora conservation and recovery. Maintaining and managing the Threatened and Priority

Flora database (TPFL) allows the department to provide accurate technical and scientific advice on threatened and priority flora to decision makers in land use planning and environmental impact assessment processes. Undertaking conservation status assessments, including nominations for listing/delisting and change of status, ensures that the most recent biological and ecological information is available to stakeholders. The department facilitates the Threatened Species Scientific Committee (TSSC) and coordinates recovery programs, including developing interim recovery plans and supporting recovery teams, to guide translocations and conservation activities involving threatened and priority flora.

### Aims

- Provide evidence-based advice for the management, protection and recovery of flora.
- Collate, manage and interpret information on the distribution, conservation status and recovery of threatened and priority flora.
- Provide a data provision service to ensure threatened and priority flora data is available within and outside of the department.
- Contribute to the assessment of environmental impact on flora conservation values for development and vegetation clearing proposals in accordance with relevant policy and legislation.
- Prepare Ministerial Authorisations to take threatened flora in a timely manner and within acceptable limits of impact to ensure the conservation of threatened flora.
- Guide strategic and coordinated recovery programs for threatened flora, including the preparation of interim recovery plans and flora translocations.
- Undertake assessments of conservation status based on all available data and prepare nominations for the TSSC.
- Develop, inform and influence policy and strategic direction relating to flora.

### Progress

- One hundred and ninety two threatened flora authorisations were issued. Of these, 91 were issued for herbarium specimen collections for identification purposes, nine were issued for scientific/research purposes and 92 were issued for land management and operational purposes.
- One hundred and fourteen new records were added to the TPFL database, of which 75 were records of new populations.
- A total of 475 data search requests for threatened and priority flora were processed (26 DBCA, 102 other government departments, 321 consultants/mining sector, and 26 other organisations).
- Conservation status assessments resulted in 47 additions to the priority flora list, change in category of 21 taxa, and delisting of five taxa after survey and taxonomic review clarified their conservation status.
- Nine nominations for threatened flora were reviewed, five for addition to the threatened flora list, two for a change in category and criteria and two for a change in criteria only.
- Conservation status was reviewed for taxa described in four draft *Nuytsia* manuscripts.
- Interim recovery plans were approved for two species of threatened flora, the first recovery plans to be made under the *Biodiversity Conservation Act 2016* (BC Act). Significant new legislative requirements for public consultation, approval and publication were negotiated and met.
- Translocation proposals were approved for six internal DBCA and two external projects.
- Impact assessment advice was provided in relation to 60 clearing permit applications, 24 other mining or development projects (53 separate advice requests) and 19 land use planning proposals with the potential to affect threatened and priority flora.
- Advice was provided on flora licenses including bio-prospecting licenses and on issues relating to the management of the Western Australian flora industry.
- Support was provided for the meeting of Threatened Flora Recovery Teams representing the South Coast, Goldfields, Swan and Warren Regions, and the Albany, and Esperance Districts.
- Volunteers in the Swan, Wheatbelt and Warren regions, and Albany and Geraldton Districts assisted in conducting surveys for many threatened and priority flora species. Volunteers from the department and the Western Australian Native Orchid Study and Conservation Group collaborated on the Adopt an Orchid project to survey and monitor 40 threatened and priority orchid species, with 138 populations monitored and 32 new populations discovered.
- Representation continued on the national working group for implementing the MoU on a Common Assessment Method for assessing threatened species. Two flora species were endorsed by the Federal Minister for formal listing under the *Environment Protection and Biodiversity Conservation Act 1999*.



- Training was provided to Department of Water and Environmental Regulation (DWER) and Department of Mines, Industry Regulation and Safety staff on the use and interpretation of threatened and priority flora data for desktop assessments of clearing permits.
- Contributed to the development of the Disturbance Approval System Phase 2 – GIS Integration by being part of the project team. Ongoing support to be provided to this project team in 2020-2021 regarding the use and provision of spatial data for threatened species and communities.
- Drafted flora fire response guidelines as part of the documentation being prepared on best practice mitigation and management actions to protect biodiversity during bushfire mitigation activities. Participated in first stage of testing of the Threatened Species and Communities database.
- Organised and presented at a workshop for Adopt an Orchid volunteers to improve data provision and strengthen community partnerships.
- Provided input into the State Native Vegetation Strategy including administrative supporting in organising and hosting a workshop for DWER to undertake departmental consultation on the issues paper.
- Provided input and advice on 14 threatened flora species' profiles for the National Action Plan for Australia's Most Imperilled Plants, coordinated by the NESP Threatened Species Recovery Hub.

### Management implications

- Enhanced data sets and lists for threatened and priority flora facilitate improved assessment and conservation.
- Updates to the TPFL database assists in resolving the status of flora and provides improved information for land use planning and management.
- Management advice, and assessment of applications to take or translocate threatened flora, assists the department and other land managers to maintain the conservation status of threatened and priority flora.
- Industry management programs and threatened flora recovery plans guide conservation outcomes.
- Provision of input into the environmental impact assessment and land use planning processes maximises the potential for positive conservation outcomes.

### Future directions

- Continue to deliver strategic direction and coordination of the conservation, management, protection and recovery of flora in an efficient manner.
- Continue to assess the conservation status of flora and prepare nominations for listing and recovery plans where necessary.
- Prepare high quality technical flora advice to internal and external stakeholders as required.
- Transition to the new Threatened Species and Communities database and ensure high quality data is maintained and shared.
- Continue to implement the BC Act, through issuing of Ministerial Authorisations and ensure processes and guidelines are in place as required.



## Fauna conservation and recovery

CF 2018-040

JM Renwick, M Davies, K Bain, A Mutton, T Johnston, A Robey, K Rick

### Context

The fauna conservation team provides a range of science based support for fauna conservation and recovery programs. The team provides advice and input on the range of recovery programs for threatened fauna, coordinates recovery programs, including developing recovery plans and supporting recovery teams, administers strategic translocation planning and conservation activities involving threatened and priority fauna. The team oversees the collation of information through capture of threatened and priority fauna records. Maintaining the Threatened and Priority Fauna database allows the department to provide accurate technical and scientific advice on threatened and priority fauna to decision makers in land use planning and environmental impact assessment

processes. The department facilitates the Threatened Species Scientific Committee (TSSC). The team facilitates the department's Animal Ethics Committee (AEC) to manage requirements for ethical consideration of animals in research and management projects.

## Aims

- Provide evidence-based advice for the management, protection and recovery of threatened and priority fauna.
- Collate, manage and interpret information and data on the presence and distribution of threatened and priority fauna.
- Provide a data provision service to ensure threatened and priority fauna data are available within and outside the department.
- Guide strategic and coordinated recovery programs for threatened fauna, including translocations.
- Undertake assessments of conservation status based on all available data, and where appropriate, prepare nominations for the consideration of the TSSC.
- Inform policy and strategic direction relating to fauna.
- Assess applications for Ministerial Authorisations to take or disturb threatened fauna under section 40 of the *Biodiversity Conservation Act 2016*, (BC Act) to ensure risks to individual animals and subpopulations are minimised during survey, monitoring and relocation activities.
- Provide technical advice on assessment of environmental impacts on fauna for development and vegetation clearing proposals, and licence applications to take fauna for relocation, scientific and other purposes, in accordance with relevant policy and legislation.
- Ensure that animals used for scientific purposes are cared for and used in an ethical and humane manner and that the department meets its commitments under the *Animal Welfare Act 2002*, its *Licence to use animals for scientific purposes*, and the *Australian Code for the Care and Use of Animals for Scientific Purposes*.

## Progress

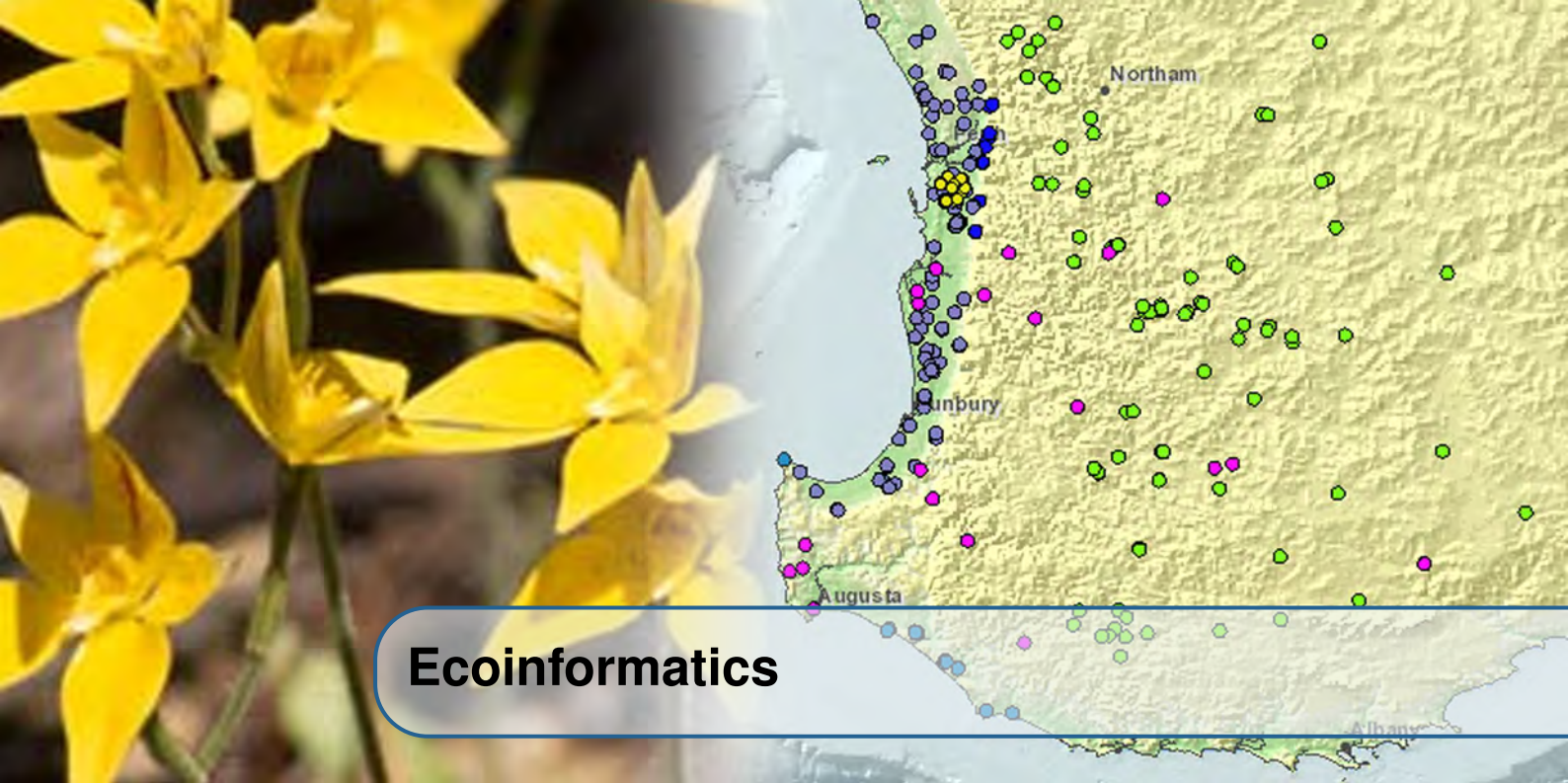
- As at 31 July 2020, under the BC Act, a total of 249 fauna species were listed as threatened species (57 as critically endangered, 58 as endangered and 134 as vulnerable), 23 as extinct species, and 88 as specially protected species (seven conservation dependent, seven other specially protected and 74 migratory species). There were 219 species on the department's priority fauna list.
- Support and advice was provided to the national Wildlife and Threatened Species Bushfire Recovery Expert Panel on key priorities for Western Australian species impacted by the 2019-2020 summer bushfires.
- A total of 39,251 records of sightings, captures or evidence of threatened, specially protected and priority fauna were added to the Threatened and Priority Fauna database, bringing the total number of records in the database to 107,981.
- Three hundred and forty two threatened and priority fauna data searches and extract requests were performed and numerous responses were provided to fauna enquiries.
- Two hundred and twenty one Ministerial Authorisations to take or disturb threatened fauna under section 40 of the BC Act were assessed and granted.
- Continued to support Wildlife Protection Branch by providing expert technical advice on applications for fauna licences under the Biodiversity Conservation Regulations 2018.
- Thirty seven formal written advice requests were provided in relation to assessment of environmental impacts associated with clearing permit applications, mining development projects and land use planning proposals, in addition to numerous informal requests for potential or hypothetical significance of impacts on threatened or priority fauna.
- Advice and support was provided to 17 fauna recovery teams to ensure continued conservation and appropriate management for threatened species.
- Provided advice and reviewed proposals for translocation and captive-bred releases for threatened fauna species including duffers, numbats, western swamp tortoises, Shark Bay bandicoot, rufous hare-wallaby and Shark Bay mouse.
- Contributed to the national review related to the commercial harvesting of kangaroos.
- The AEC met six times, conducted a total of 302 assessments, approved 11 new projects and approved the renewal of 38 projects. There were 128 active projects that covered the following broad areas of research and monitoring: fauna monitoring, general fauna research, translocations, fauna surveys, education, feral animal control research and marine research.

## Management implications

- Enhanced data sets and lists for threatened and priority fauna facilitate improved assessment and conservation.
- Updates to the threatened fauna database assists in supporting nominations and reviews of the conservation status of fauna and provides improved information for impact assessment, land use planning and management.
- Management advice, and assessment of applications for authorisations and licences to take and disturb fauna, or for the translocation of threatened fauna, assists the department and other land managers to maintain or improve the conservation status of threatened and priority fauna.
- Departmental animal welfare requirements are maintained through operation of the AEC.
- Threatened fauna recovery plans and teams guide conservation outcomes.
- Provision of input into the environmental impact assessment and land use planning processes maximises the potential for positive conservation outcomes.

## Future directions

- Continue to deliver strategic direction and coordination of the conservation, management, protection and recovery of fauna in an efficient manner.
- Transition to the new threatened species and communities database, and ensure high quality data is maintained and shared.
- Prepare fauna advice within requested time frames.
- Finalise the draft guideline for the survey and relocation of bilby, in relation to vegetation clearing and other significant disturbance activities.
- Continue to ensure that the correct processes and advice is in place for the department to meet its requirements under the *Animal Welfare Act 2002*.
- Continue to implement the BC Act, through issuing of Ministerial Authorisations and processes and guidelines are in place as required.



## Ecoinformatics

**Program Leader: Julian Tonti-Filippini** The Ecoinformatics Unit manages and make available the digital biodiversity assets of Biodiversity and Conservation Science. The unit compiles and maintains corporate databases and data warehouses. In particular, it develops and maintains the online portal *NatureMap* that publishes maps, lists and datasets of Western Australian species. The unit collaborates on projects involving complex information management and analysis, such as identifying broad-scale patterns of plant biodiversity. It also represents Biodiversity and Conservation Science, both internally and externally, on various forums that have a significant information management (IM) focus, and provides advice on a range of strategic IM issues. The Ecoinformatics Unit collaborates with various organisations in co-developing ecoinformatics tools (e.g. the NSW Office of Environment and Heritage) and data hosting (e.g. republishing fauna collections from the Western Australian Museum through *NatureMap*).



### BioSys – the Western Australian Biological Survey Database

CF 2015-024

F Mayer, J Tonti-Filippini

#### Context

A key strategy in conserving biodiversity is collecting field observation data that can be transformed into information, and then knowledge to inform decision-making. This biological survey is an important component of conservation programs, and because of Western Australia's size, and the remoteness and inaccessibility of many sites, data collection is typically expensive, and data sets are often irreplaceable. A corporately accessible database is required to capture biological survey data and ensure it is readily available. The Western Australian Biological Survey Database, BioSys, is a corporate application designed to load, curate and export complex ecological data. It aims to address the risks and issues described above by providing a secure, central, scalable, and accessible data repository based on modern, modular architecture.

#### Aims

- Build a corporate application for storing, curating and distributing ecological data, that allows users to manage their own data sets, and increases accessibility of ecological data to departmental users and systems.

## Progress

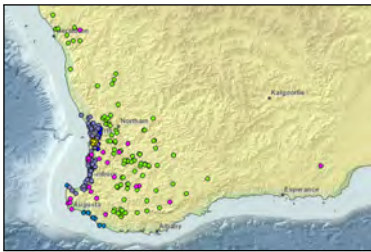
- BioSys is the primary repository for new biodiversity data sets within Biodiversity and Conservation Science. It has been integrated into the data workflow supplying *NatureMap*. There are currently 30 major projects comprising 233 data sets and 836,594 records within the repository. Legacy data sets are being migrated to the new system.
- The Biodiversity Information Office has now been approved by the State Government and will be taking ownership of BioSys as a core component of the Office.

## Management implications

- Reporting, research and analysis will be more effective and efficient through improved data consistency and availability. In turn, this will better inform decision-making and enhance conservation outcomes.
- Data will be better protected from loss arising from staff turnover or changing storage technologies, and will benefit from improved security and backup.
- Improved integration between systems will reduce the implementation cost on new projects through software re-use and more efficient data access.
- The system will facilitate improved compliance with government requirements for knowledge management and open data.
- Collaborations with external partners represents a major return on investment for the department that is building the functionality and utility of BioSys.

## Future directions

- The data collection tool is being reviewed for customisation for use within the department. A variety of applications are under consideration internally.



## Online GIS biodiversity mapping (*NatureMap*)

CF 2011-106

J Tonti-Filippini

## Context

A major challenge in managing the conservation estate in Western Australia, with its enormous biodiversity, is providing access to current and reliable information on species and their populations. Countless surveys and research projects have been undertaken within Western Australia over a long period of time, resulting in many data sets and reports that contain valuable and essential information for the ongoing management of this unique biota. Tools are required to enable conservation workers, industry and the public to more easily discover, assemble, analyse and report on biodiversity information that has been collected.

## Aims

- Digital delivery of authoritative scientific information on the distribution and identity of major elements of the Western Australian biota from a single, online portal.

## Progress

- Occurrence records number over 5.3 million from 221 data sources.
- An additional 209 new registrations were recorded, bringing the total from 2,904 to 3113, a 7 percent increase.
- Interactions between *NatureMap* and BioSys have been established providing integration of plot based data sets into *NatureMap*.

### Management implications

- *NatureMap* provides a long-term repository for conserving and protecting the department's digital biodiversity data assets, so that knowledge can continue to be informed and improved through staff succession.
- *NatureMap* significantly reduces the time spent searching for point-based biodiversity data as well as easing the process of generating species lists for any area in Western Australia.

### Future directions

- Continued incorporation of new and historical survey data into *NatureMap*.
- The functions of *NatureMap* will be incorporated into the Biodiversity Information Office.



## External Partnerships

Partners	Project Title	External Funding	Departmental Involvement
Atlas Iron, Fortescue Metals Group, Iron Ore Holdings, Roy Hill, Main Roads Western Australia	Ecology and management of the northern quoll in the Pilbara	\$195,000	J Dunlop, K Morris, S van Leeuwen, L Gibson
Atlas Iron, Main Roads Western Australia	Ecology and management of the Pilbara olive python	\$125,000	D Pearson, S van Leeuwen, K Morris, L Gibson, M Cowan
Atlas Iron, Rio Tinto, BHP, Kanyirninpa Jukurrpa, BatCall WA	Ecology and management of the Pilbara leaf-nosed bat	\$320,000	L Gibson, K Ottewell, L Umbrello
Atlas Iron, Roy Hill	Investigating the interactions between feral predators in the Pilbara	\$240,000	K Morris, S van Leeuwen, D Moro
Audelia Resources	Genetic assessment of sub-populations of <i>Marianthus aquilonaris</i>	\$130,000	M Byrne, T Hopley
Australian Biological Resources Study, Queensland Herbarium, Northern Territory Herbarium, University of the Western Cape (South Africa)	Towards an eFlora treatment of <i>Tephrosia</i> (Pers.) in Australia: taxonomic revision of the genus in Western Australia and the Northern Territory	\$515,000	R Butcher, T Macfarlane
Australian Institute of Marine Science, Australian National University	Coral reef fish recruitment study	\$13,000	S Wilson, T Holmes
Australian Institute of Marine Science, CSIRO	Mapping flatback turtle foraging areas in the Kimberley	\$1,000,000	T Tucker, S Whiting
Australian Institute of Marine Science, The University of Western Australia	Understanding the early off-shore movement of flatback turtle hatchlings and the effects of anthropogenic light	\$400,000	S Whiting
Australian Nuclear Science and Technology Organisation	Investigation of radionuclide contamination at Montebello Islands to understand implications for turtles and researchers	\$20,000	S Whiting

Partners	Project Title	External Funding	Departmental Involvement
Australian Research Council, Australian National University, University of Adelaide, Australian Museum, Western Australian Museum	Island genomes: enhancing management of Australia's threatened mammals	\$460,000	K Ottewell, M Byrne
Australian Research Council, Australian National University, Western Australian Museum, South Australian Museum	Phylogenomic assessment of conservation priorities in two biodiversity hotspots: the Pilbara and the Kimberley	\$570,000	M Byrne
Australian Research Council, Charles Darwin University, Save the Gouldian Fund, Ballangarra Aboriginal Corporation, World Wide Fund for Nature, Wild Spy Pty Ltd, National Drones Pty Ltd, The University of Auckland, Kimberley Land Council	Movement ecology of granivores: informing fire management of savannas	\$400,000	I Radford
Australian Research Council, Curtin University, Royal Botanic Gardens and Domain Trust (Mt Annan Botanic Gardens), The University of Western Australia, Australian Nuclear Science and Technology Organisation, United States Department of Agriculture, University of South Dakota (USA)	Advanced cryobanking for recalcitrant-seeded Australian rainforest plants	\$732,000	R Bunn
Australian Research Council, Flinders University, CSIRO, The University of Western Australia	Optimising seed sourcing for effective ecological restoration	\$460,000	S Krauss, D Merritt
Australian Research Council, Murdoch University, Western Australian Museum, Roy Hill	Building resilience to change for mammals in a multi-use landscape	\$536,000	K Ottewell, L Gibson, M Byrne, S McArthur, R Shaw
Australian Research Council, Murdoch University	Optimising fire regimes for fire risk and conservation outcomes in <i>Banksia</i> woodlands in the Perth area	\$455,000	B Miller, K Ruthrof
Australian Research Council, The University of Western Australia, Australian National University	The evolution and conservation consequences of promiscuity in plants pollinated by vertebrates	\$1,400,000	S Krauss
Australian Research Council, The University of Western Australia, University of Adelaide, Australian Genome Research Facility	Seagrass adaptation and acclimation responses to extreme climatic events	\$525,000	S Krauss
Australian Research Council, University of Queensland, The University of Western Australia	Assessing the ecosystem-wide risks of threatened species translocation	\$311,377	M Byrne
Australian Research Council, University of Queensland, University of Western Australia, Perth Zoo, Melbourne Zoo, Taronga Zoo, Adelaide Zoo, Shedd Aquarium, Vancouver Aquarium, North Carolina Aquarium, St Louis Zoo, Denver Zoo, Oregon Zoo, Philadelphia Zoo, Brookfield Zoo, Oregon Zoo, Woodland Park Zoo	Supporting family environmental learning and behaviour identifying, designing and testing transformative values-based education programs in zoos and aquariums	\$236,822	P Mawson



Partners	Project Title	External Funding	Departmental Involvement
Australian Research Council, University of Sydney, Department of the Environment and Energy, Australian Reptile Park	Predicting the ecological impact of cane toads on native fauna of north western Australia	\$503,000	D Pearson
Australian Research Council, University of Tasmania, Department of Primary Industry - New South Wales, Department of Environment, Water and Natural Resources - South Australia, Smithsonian (USA)	Functional responses of rocky reef communities to effects of fishing and other anthropogenic stressors	\$900,000	T Holmes
Australian Research Council, University of Western Sydney, Murdoch University	Do hotter and drier regions harbour adaptive variation for climate change	\$281,505	M Byrne, R Mazanec
BHP, CyMod Systems, Australian Nuclear Science and Technology Organisation	Hydrogeochemistry of Walyarta Springs	\$120,000	J Rutherford
Beyond fire frequency: understanding seasonal timing of fire for ecosystem management	Beyond fire frequency: understanding seasonal timing of fire for ecosystem management	\$453,000	B Miller, C Yates, K Ruthrof
BioPlatforms Australia, Centre for Biodiversity Analysis, Western Australian Museum, Australian Museum, South Australia Museum, Museum of Victoria, University of Adelaide	Oz Mammals Genomics	\$1,112,000	M Byrne, K Ottewell
BioPlatforms Australia, Ian Potter Foundation, Royal Botanic Gardens Victoria, Centre for Australian Plant Diversity Research, Australian Tropical Herbarium, Royal Botanic Gardens and Domain Trust, Southern Cross University	Genomics for Australian plants	\$1,800,000	M Byrne, S Krauss
Biodiversity Fund, Warren Catchment Council, CSIRO	Restoring natural riparian vegetation systems previously infested by blackberry along the Warren and Donnelly Rivers	\$2,945,000	M Byrne, T Hopley
Biologic Environmental Survey Pty Ltd	Developing and refining microclimate spatial layers for the Pilbara IBRA region to identify refugia for terrestrial mammals	Nil	K Ottewell, J Kinloch, B Huntley
Bushfire and Natural Hazards CRC	Bushfire and Natural Hazards CRC	Nil	L Mccaw
CSIRO Future Science Fellowships in Environomics	Lifespan estimation in marine turtles using genomic promoter CpG density	\$310,000	T Tucker, S Whiting
CSIRO, Australian SuperSite Network, Terrestrial Ecosystem Research Network, National Research Infrastructure for Australia	Great Western Woodlands SuperSite	Nil	S van Leeuwen, M Byrne
CSIRO, National Environmental Science Program - Marine Biodiversity Hub	Dugong population and habitat survey - Shark Bay and Ningaloo	\$123,622	H Raudino, K Waples, K Murray
CSIRO, National Environmental Science Program - Northern Australia Environmental Resources Hub, Kimberley Land Council	Impacts and management of an invasive weed in the Fitzroy Catchment	\$140,000	S van Leeuwen

Partners	Project Title	External Funding	Departmental Involvement
CSIRO, National Environmental Science Program - Threatened Species Recovery Hub, Australian Wildlife Conservancy, Bush Heritage Australia, Department of the Environment and Energy	Explaining and predicting the occurrence of night parrots ( <i>Pezoporus occidentalis</i> ) using GIS and ecological modelling	\$38,000	A Burbidge
CSIRO, The University of Western Australia	Marine turtle stable isotopes	Nil	T Tucker, S Whiting
CSIRO, The University of Western Australia	Understanding and quantifying impacts of invasive <i>Pasiflora foetida</i> on freshwater crocodiles in the east Kimberley	\$40,000	S van Leeuwen
CSIRO	Coral recruitment patterns in the Dampier Archipelago, Western Australia	\$8,000	M Moustaka
CSIRO	Fire regimes and impacts in transitional woodlands and shrublands	Nil	C Yates, C Gosper
CSR Gyprock	Wetland flora and fauna of the Jurien coast	\$138,000	A Pinder, M Lyons, K Quinlan, R Coppen
Central Desert Native Title Services	Fire scar mapping - Kiwirrkurra Indigenous Protected Area	\$1,000	K Zdunic, G Loewenthal
Charles Sturt University	Introduced predator interactions with an endangered native predator, the Pilbara northern quoll	\$78,000	J Dunlop
Chevron - Gorgon Net Conservation Benefit, James Cook University, Australian Research Council Centre of Excellence for Coral Reef Studies	Decision support system for prioritising and implementing biosecurity on Western Australia's islands	\$5,000,000	C Lohr, K Morris, L Gibson
Chevron - Net Conservation Benefit	Cat eradication on Dirk Hartog Island	\$3,000,000	D Algar, M Johnston, J Fletcher, N Hamilton, C Tiller, M Onus
Chevron - Wheatstone	Conserving critical seagrass habitat for dugong: an integrated assessment across the Pilbara	\$1,236,754	K Waples, H Raudino
Chevron	Translocations of mammals from Barrow Island: offset program	\$9,500,000	K Morris, N Thomas, C Sims, J Angus, S Garretson, M Blythman
Cooperative Research Centre for Honey Bee Products, University of Adelaide, Dijilarup Manuka Pty Ltd, Spring Gully Foods	Understanding the genetic diversity of native <i>Leptospermum</i> species for high value honey products	\$416,100	M Byrne, R Binks
Curtin University, Australian Institute of Marine Science, The University of Western Australia, Department of Primary Industry and Regional Development, Flinders University, Department of Environment and Water (SA), Deakin University, Department of Primary Industries (NSW), University of Tasmania, CSIRO, FinPrint	Australian wide synthesis of baited video data to answer broad-scale ecological questions	Nil	T Holmes, J Goetze, S Wilson

Partners	Project Title	External Funding	Departmental Involvement
Curtin University, The University of Western Australia, University of Queensland, Victoria University of Wellington	Development of a geo-ecological reef carbonate system model to understand responses of reefs and reef-fronted shorelines to climate change	Nil	C Ross, R Evans
Curtin University, The University of Western Australia, Society for Ecological Restoration Australasia, BHP, Sinosteel Midwest Corporation, Mineral Resources, Hanson Construction Materials, Karara Mining Limited	ARC Training Centre for Mining Restoration	\$4,961,622	D Merritt, S Krauss, J Stevens
Curtin University, The University of Western Australia	The energetic basis to seed longevity and storage	\$336,000	D Merritt
Dambimangari Wanjina-Wunggurr Aboriginal Corporation, Bardi and Jawi Niimidiman Aboriginal Corporation	Benthic biodiversity surveys of intertidal <i>wooddooroo</i> (coral reefs) in the Lalang-garram, North Kimberley and proposed Buccaneer marine parks	\$214,500	W Robbins, T Holmes, E D'Cruz
Department of Industry, Innovation and Science, The University of Western Australia	Eco-engineering solutions to improve mine-site rehabilitation outcomes	\$1,314,652	D Merritt, T Erickson
Department of Organismal Biology & Ecology, Colorado College (USA), St John University (USA)	Phylogenetics and floral symmetry development of the core Goodeniaceae	Nil	K Shepherd
Department of Planning, Lands and Heritage, Perth NRM	Hydrology of the Ashfield Flats	Nil	G McGrath, J Rutherford, A Pinder, B Huntley
Department of Primary Industries and Regional Development, CSIRO, Australian Institute of Marine Science, Curtin University	Connectivity of coral trout populations between individual reefs on the Rowley Shoals	Nil	W Robbins, E D'Cruz
Department of Primary Industries and Regional Development	Developing novel remote camera approaches to assess and monitor the population status of Australian sea lions	Nil	K Waples
Department of Water and Environmental Regulation, Water Corporation	Millstream riparian vegetation monitoring	\$2,000	B Huntley
Department of Water and Environmental Regulation	Improving wetland mapping data sets for Western Australia	\$208,800	M Coote, F Felton, K Zdunic, G Loewenthal, A Turnbull
Department of Water and Environmental Regulation	Swan Canning Estuary microplastics and plastics survey	\$75,000	P Novak, K Trayler
Department of Water and Environmental Regulation	Statewide vegetation statistics and south-west vegetation complex statistics (CAR analyses)	\$14,000	J Kinloch, G Pitt
Department of the Environment and Energy - Threatened Species Commissioner, Rangelands NRM Western Australia	Development of Hisstory bait for feral cat control	\$250,000	M Johnston, N Hamilton, M Onus, D Algar
Department of the Environment and Energy	Western Australian black spot biological survey campaign	\$170,000	S van Leeuwen, A Pinder, M Lyons, M Cowan

Partners	Project Title	External Funding	Departmental Involvement
Digital Earth Australia, Geoscience Australia, Earth Observation Governmental Network	Remote sensing based marine monitoring framework development with Geoscience Australia	\$14,000	B Huntley, K Murray, K Zdunic, G Pitt, K Bancroft, W Robbins
Digital Life Project, University of Massachusetts - Amherst (USA), Murdoch University	Exploring the benefits of state-of-the-art 3D imaging techniques to create 3D digital and physical specimens of live flat-back turtles for science, conservation and education	Nil	S Fossette-Halot, S Whiting, T Tucker
Ecological Horizons, Fortescue Metals Group, Roy Hill	Testing the efficiency and efficacy of Felixer feral cat grooming traps	\$85,000	J Dunlop
European Centre for Medium Range Weather Forecasting, Reading, UK	Using machine learning to predict fire ignition occurrences from lightning forecasts	Nil	L Mccaw
Florida International University, Australian Institute of Marine Science, James Cook University	Global FinPrint	Nil	J Goetze
Forest Products Commission	An investigation into identifying wild sandalwood using aerial imagery	\$ 5,700	R Van Dongen
Fortescue Metals Group, Millenium Minerals, Roy Hill	Ecology and management of the bilby in the Pilbara	\$2,005,000	M Dziminski, K Morris, F Carpenter, S van Leeuwen
Fremantle Ports	Fremantle Marine Quality Monitoring Program	\$30,659	S Hoeksema, K Trayler
Geocatch, Edith Cowan University, Department of Primary Industries and Regional Development	The long-term monitoring of seagrass communities in Geographe Bay	\$10,000	B French
Global Coral Reef Monitoring Network	The Global Coral Reef Monitoring Network (GCRMN) Status of Coral Reefs of the World report	Nil	T Holmes, S Wilson, C Ross, J Goetze, W Robbins, E D'Cruz, R Evans, M Moustaka
Great Victoria Desert Biodiversity Trust	Fire Mapping in the Great Victoria Desert	\$86,279	J Rusalleda Alvarez, R Van Dongen
Hanson Construction Materials	Restoring <i>Banksia</i> Woodland communities after mining	\$25,000 pa	J Stevens, W Lewandrowski
James Cook University, The University of Western Australia, Australian Institute of Marine Science, CSIRO Marine and Atmospheric Research, Department of Primary Industries and Regional Development, Western Australian Museum	Temporal and spatial variation in coral cover on Western Australian reefs	Nil	S Wilson
James Cook University	Human impacts on coral reef communities	Nil	S Wilson
James Cook University	Establishing baselines and assessing vulnerability of commercially harvested corals across northern Australia	\$150,000	S Wilson, M Moustaka
Kanyirninpa Jukurrpa	Western Desert Land Cover Classification Pilot Project	\$17,000	K Zdunic, J Chapman
Landgate	Western Australian State Government Data Catalogue	\$12,000	F Mayer

Partners	Project Title	External Funding	Departmental Involvement
Main Roads Western Australia, Kimberley Land Council, Rangelands NRM Western Australia, Nyamba Buru Yawuru Ltd, Walalakoo Aboriginal Corporation, Bardi Jawi Aboriginal Corporation	Conservation and management of the bilby ( <i>Macrotis lagotis</i> ) on the Dampier Peninsula, Kimberley	\$600,000	M Dziminski, R McPhail, F Carpenter
Metals X Limited	Great Sandy Desert restoration	\$127,128	J Stevens
Millennium Seed Bank, Australian Seed Bank Partnership, Department of the Environment and Energy	Seed collection, storage and biology	\$12,000	A Crawford
Mineral Resources Ltd, The University of Western Australia	Integrated conservation and translocation of the threatened banded ironstone species <i>Tetratheca erubescens</i> (Elaeocarpaceae)	\$997,000	J Stevens, B Miller, S Krauss, D Merritt, W Lewandrowski, C Elliott
Murdoch University, Curtin University	Evidence based management of foxes adjacent to turtle beaches in Western Australia	\$300,000	S Whiting
Murdoch University	Collation of historic data for Shark Bay, Marmion and Shoalwater Islands Marine Parks.	\$20,000	S Wilson, A Kendrick
Murdoch University	Baseline microbial surveys in Swan Canning	Nil	K Trayler, S Hoeksema
Murdoch University	Swimming and diving performances of inter-nesting flatback turtles	\$50,000	S Fossette-Halot, S Whiting, T Tucker
Murdoch University	Using Unmanned Aerial Vehicles (UAVs) to investigate visual detection probability of coastal dolphins during aerial surveys	\$115,757	K Waples, H Raudino
Murdoch University	The health status of marine turtles in northern and western Australia	\$200,000	S Whiting
Murdoch University	Genetic studies of Pilbara EPBC Act listed threatened vertebrate fauna	\$235,000	K Morris, D Pearson, S van Leeuwen, M Cowan, J Dunlop
NSW Rural Fire Service	A new National Fire Danger Rating System for Australia	Nil	L Mccaw
National Environmental Science Program - Northern Australia Environmental Resources Hub, Environs Kimberley, Kimberley Land Council	Securing the future for bilby in the Fitzroy Catchment / West Kimberley	\$540,000	M Dziminski, R McPhail (Kimberley Region), F Carpenter
National Environmental Science Program - Threatened Species Recovery Hub	Project 4.3: Improving threatened plant reintroduction success and species recovery	\$699,000	L Monks, R Dillon, M Byrne
National Science Foundation (USA)	Systematics and biogeography of the Inocybaceae	\$19,000	N Bougher
Net Conservation Benefits, CSIRO	Molecular characterisation of stinking passionflower ( <i>Passiflora foetida</i> )	\$913,000	M Byrne, T Hopley, S van Leeuwen
Office of Environment and Heritage (NSW)	Evaluating BioSys within the Office of Environment and Heritage (NSW) data environment	\$150,000	J Tonti-Filippini

Partners	Project Title	External Funding	Departmental Involvement
Parks Australia and other Christmas Island land management organisations	Christmas Island cat eradication	\$250,000	D Algar, N Hamilton
Rio Tinto, BHP	Seed collection zones for the Pilbara	\$450,000	M Byrne, R Binks, S van Leeuwen
Rio Tinto	Vegetation cover change assessment on Yarraloola and Red Hill stations	\$8,600	R Van Dongen
Rio Tinto	Introduced predator control and baiting program - Yarraloola	\$3,000,000	R Palmer, H Anderson, K Morris
Rio Tinto	Identification botanist position at the Western Australian Herbarium	\$120,000	J Huisman, S Dillon
RioTinto	Genetic assessment of Western Range populations of <i>Aluta quadrata</i>	\$83,000	M Byrne, R Binks, S van Leeuwen
Roy Hill, Atlas Iron, CSIRO, Pilbara Corridors, Rangelands NRM Western Australia, Pilbara Mesquite Management Committee	Strategic weed assessment of the Pilbara Bioregion	\$350,000	S van Leeuwen
Royal Botanic Gardens - Kew, University of Portsmouth (UK)	The <i>Styloidium</i> phylogeny and pollination project	Nil	J Wege
SCORE-REEF	Spatio-temporal variability of coral reefs at the global scale: causalities, idiosyncrasies and implications for ecological indicators	Nil	S Wilson, T Holmes, J Goetze, C Ross
South Coast NRM	Conservation of the threatened Australasian bittern in south-western Australia	Nil	A Pinder, A Clarke
South Coast NRM	Inundation products derived from remote sensing data for Lake Warden, Lake Gore wetlands and neighbouring systems in the south-west and the rest of Western Australia	\$16,600	B Huntley
South Coast NRM	Implementing recovery actions for EPBC listed species of the South Coast	\$30,000	A Friend
The University of Western Australia, Department of Water and Environmental Regulation	Ashfield Flats Hydrological Project	\$10,000	G McGrath
The University of Western Australia, National Marine Fisheries Service (USA), Northern Territory Museum, Western Australian Museum, Queensland Department of Environment and Science, Pendoley Environmental, Australia Government Department of Agriculture, Water and Environment	Skeletochronology and stable isotope analyses of flatback turtles	\$400,000	T Tucker, S Whiting
The University of Western Australia	Sediment Geochemistry of Ashfield Flats Reserve	\$14,850	G McGrath
The University of Western Australia	Using tree rings to reconstruct long term rainfall patterns in south-west Western Australia	Nil	L Mccaw

Partners	Project Title	External Funding	Departmental Involvement
The University of Western Australia	Susceptibility of frogs to declining rainfall in a biodiversity hotspot	Nil	M Cowan
The University of Western Australia	Assessing the vulnerability of honey possums to climate change and habitat disturbances in south-western Australia	Nil	M Cowan
The University of Western Australia	Influence of physiology on coral-based paleothermometry under varying temperature and light regimes	Nil	C Ross
University of Adelaide, Uppsalla University, Australian Genomed Research Facility, National Research Council Italy	Understanding adaptation to improve conservation of Australian flora	\$605,188	M Byrne
University of Adelaide	Aquatic microinvertebrate identification and systematics	\$5,000	A Pinder, K Quinlan, D Cale
University of British Columbia	Meta-analysis of macroalgae and turf algae on coral reefs in the Indian and Pacific Oceans	Nil	T Holmes, C Ross
University of Michigan - Department of Ecology and Evolutionary Biology	Contemporary ecological factors and historical evolutionary factors influencing the distribution and abundance of arid-zone reptile species in space and time	Nil	M Cowan
University of Queensland, Karara Mining Limited, The University of Western Australia, Curtin University	Eco-engineering soil from mine tailings for native plant rehabilitation	\$590,000	J Stevens
University of Queensland	Development of a male dibbler and numbat fertility index through the evaluation of spermatorrhoea characteristics to determine if there is a male factor in breeding success	Nil	P Mawson
Victoria University of Wellington	Drivers of crustose coralline algae on coral reefs: direct and indirect effects of marine heat-waves	Nil	C Ross
Western Australian Museum	<i>NatureMap</i> : data sharing and joint custodianship	Nil	J Tonti-Filippini

## Student Projects

DBCA Officer	Student	Academic	Project Title	Duration	Page
D Algar	S Comer (PhD)	Dr D Roberts (The University of Western Australia), Dr P Speldewinde (The University of Western Australia)	Ecology of the feral cat in coastal heaths of the south coast of Western Australia	2014 – 2021	<a href="#">157</a>
A Burbidge	M Lohr (PhD)	Dr R Davis (Edith Cowan University)	Responses of southern boobooks to threatening processes across urban, agricultural and woodland ecosystems	2017 – 2019	<a href="#">157</a>
A Burbidge	N Leseberg (PhD)	A/Prof R Fuller (University of Queensland), Dr S Murphy (Australian National University), Dr J Watson (University of Queensland)	Ecology and conservation biology of the night parrot	2017 – 2019	<a href="#">158</a>
M Byrne	B Nordstrom (PhD)	A/Prof N Mitchell, S Jarman (The University of Western Australia)	Assisted colonisation of the western swamp tortoise ( <i>Pseudemydura umbrina</i> ): the role of energy requirements in translocation decisions	2020 – 2024	<a href="#">158</a>
M Byrne	S Walters (PhD)	Dr P Nevill (Curtin University), A/Prof G Wardell-Johnson (Curtin University), Dr T Robinson (Curtin University)	Adaptive and phylogeographic variation in sympatric parasitic and non-parasitic species in Western Australia	2017 – 2020	<a href="#">159</a>
M Byrne	J Bruce (MSc)	Dr A Koenders (Edith Cowan University), Prof P Horwitz (Edith Cowan University), Dr K Lemson (Edith Cowan University), Dr Q Burnham (Edith Cowan University)	<i>Reedia spathacea</i> F. Muell.: a study of phylogeography, population structure and co-occurrence	2016 – 2020	<a href="#">159</a>
M Byrne	N Delnevo (PhD)	Dr E van Etten (Edith Cowan University), Prof W Stock (Edith Cowan University)	<i>Conospermum undulatum</i> : insights into genetics and ecology of an endangered species	2017 – 2020	<a href="#">160</a>



DBCA Officer	Student	Academic	Project Title	Duration	Page
M Byrne, C Yates	R Dillon (PhD)	Prof M Waycott, Dr R Standish (The University of Western Australia)	Mating systems, reproductive output and progeny fitness of translocated plant populations compared to wild populations	2017 – 2020	160
M Byrne, C Yates	L Monks (PhD)	Dr R Standish (The University of Western Australia)	Factors affecting the success of threatened flora translocations	2016 – 2020	161
J Cosgrove, K Traylor	M Jung (PhD)	Dr M Fraser (The University of Western Australia), Dr BC Martin (The University of Western Australia)	Tracking seagrass condition: development and application of novel molecular biomarkers	2020 – 2023	161
J Dunlop	H Moore (PhD)	Dr D Nimmo (Charles Sturt University), Prof D Watson (Charles Sturt University), Dr L Valentine (The University of Western Australia)	The influence of invasive predators and fire regimes on northern quolls in the Pilbara	2017 – 2020	162
S Fossette-Halot	J Hounslow (PhD)	Dr AC Gleiss (Murdoch University)	Ecology of flatback turtles ( <i>Natator depressus</i> ) at a coastal foraging ground, Western Australia	2019 – 2023	162
S Fossette-Halot, S Whiting	C Avenant (PhD)	A/Prof G Hyndes (Edith Cowan University)	Understanding predator-prey interactions between ghost crabs and marine turtles for better management of an endangered species	2019 – 2023	162
S Fossette-Halot	M Gammon (PhD)	A/Prof N Mitchell, G McGrath	Predicting the vulnerability of flatback turtle rookeries to a changing climate	2018 – 2022	163
S Fossette-Halot	J Stubbs (PhD)	Dr M Vanderklift (The University of Western Australia), A/Prof N Mitchell	Foraging ecology and energetics of green turtles in the Ningaloo coast world heritage area	2017 – 2019	163
J Goetze	LH Hellmrich (BSc Honours)	Prof E Harvey (Curtin University)	A cost benefit analysis for the collection of reef fish density data with a micro remote operated vehicle versus SCUBA divers.	2019 – 2020	164
J Goetze	ER Rastion (PhD)	Prof E Harvey (Curtin University)	Integrated study of shallow and deep-sea fish communities status and their main stressors in a highly dynamic Galapagos seascape	2018 – 2022	164
J Goetze	KS Schramm (MSc)	Prof E Harvey (Curtin University)	A comparison of stereo-BRUV, diver operated and remote stereo-video transects for assessing reef fish assemblage	2018 – 2020	165
J Goetze	B Price (MSc)	Prof E Harvey (Curtin University)	Cyclone impact or natural variation? Assessment of damage on coral and fish in Kubulau District, Fiji by cyclone Winston	2018 – 2020	165
J Goetze	MC Márquez (PhD)	Prof E Harvey (Curtin University)	Conservation of elasmobranchs - ecology, public perception, and legal protections	2019 – 2023	166

BCA Officer	Student	Academic	Project Title	Duration	Page
T Holmes	S Zarco (PhD)	Dr T Wernberg (The University of Western Australia), Dr T Langlois (The University of Western Australia)	Persistence of tropical herbivorous fish in temperate ecosystems and its impact on habitat-forming macrophytes	2017 – 2021	166
S Krauss, B Miller	Ms L Ducki (BSc Honours)	Dr R Standish (Murdoch University)	Does a restoration plant community trajectory track that of the soil biota through a 30-year post-mining chronosequence?	2019 – 2021	167
S Krauss	J Kestel (BSc Honours)	Dr P Grierson (The University of Western Australia), Prof S Hopper (The University of Western Australia)	Genetic consequences of bird pollination for the catspaw <i>Anigozanthos humilis</i>	2018 – 2019	167
S Krauss	W Thomas (BSc Honours)	Dr P Grierson (The University of Western Australia)	Conservation genetics of the critically endangered <i>Styphelia longissima</i>	2018 – 2019	167
S Krauss, J Stevens	B Mirfakhraei (PhD)	Dr E Veneklaas (The University of Western Australia)	A genealogical assessment of seed sourcing strategies for plant community restoration under environmental change.	2017 – 2020	168
S Krauss	B Ayre (PhD)	Prof S Hopper (The University of Western Australia)	Novel consequences of bird pollination in the kangaroo paw <i>Anigozanthos manglesii</i>	2015 – 2019	168
S Krauss	N Bezemer (PhD)	Prof S Hopper (The University of Western Australia)	Evolution and conservation consequences of bird pollination: an ecological and genetic study of mating, pollen dispersal and recruitment in <i>Eucalyptus caesia</i>	2016 – 2020	169
C Lohr	S Treloar (MSc)	Dr R Davis (Edith Cowan University), Dr A Hopkins (Edith Cowan University)	Resource competition between co-existing threatened mammals in a predator-free enclosure in central Western Australia	2019 – 2020	169
C Lohr	B Palmer (PhD)	Dr L Valentine (The University of Western Australia), Prof R Hobbs (The University of Western Australia)	Reintroduced digging mammals and ecosystem restoration	2018 – 2021	169
P Mawson	G Wilkinson (MSc)	Prof P Horwitz (Edith Cowan University)	The effect of diet on the growth and reproduction of western swamp tortoise at Perth Zoo	2018 – 2019	170
P Mawson	J Hale (MSc)	Dr N Malone (University of Auckland)	Within group social dynamics and pair-bonds in captive and rescued Javan gibbons	2018 – 2019	170
P Mawson	J Scherpenhuizen (PhD)	Dr R Friere (Charles Sturt University)	Evaluation of the welfare and reproductive biology of captive tigers using non-invasive conservation physiology techniques	2017 – 2020	171
P Mawson	F Coiacetto (PhD)	A/Prof K Warren (Murdoch University)	Hindlimb paralysis syndrome in Carnaby's cockatoos	2015 – 2019	171

DBCA Officer	Student	Academic	Project Title	Duration	Page
P Mawson	E Hoffmann (PhD)	A/Prof N Mitchell	The effect of incubation temperature on development rates of <i>Geocrinia alba</i> and <i>G. vitellina</i> frog embryos	2018 – 2020	<a href="#">172</a>
P Mawson	K Wood (PhD)	Dr T Hyndman (Murdoch University), A/Prof K Warren (Murdoch University), Dr S Vitali (Murdoch University)	The prevalence of arenavirus, bornavirus, nidovirus/coronavirus, sunshinevirus and ferlavirus in captive and wild populations of Stimson pythons, pygmy pythons and carpet pythons	2017 – 2019	<a href="#">172</a>
R Mazanec	K Bhandari (PhD)	Dr E Veneklaas (The University of Western Australia), Dr M Renton (The University of Western Australia)	Predicting effects of climate change and thinning on growth, health and water yield of jarrah and karri stands using individual-based modelling	2018 – 2020	<a href="#">173</a>
L Mccaw	H Etchells (PhD)	Dr P Grierson (The University of Western Australia), Dr A O'Donnell (The University of Western Australia)	The impacts of severe wildfire on the interactions among regenerating vegetation, fungi and small foraging marsupials in south-west Australia	2017 – 2020	<a href="#">173</a>
G McGrath	Mr L McCauley (MSc)	Associate Professor S Thompson (The University of Western Australia), Dr G Skrzypek (The University of Western Australia), Dr E Veneklaas (The University of Western Australia)	The dynamic demography of water ages our trees are using	2020 – 2020	<a href="#">174</a>
G McGrath	Mr J Barrett (MSc)	Associate Professor M Leopold (The University of Western Australia)	Resistivity Geophysics Assessment of Hyporheic Exchange	2019 – 2020	<a href="#">174</a>
D Merritt, T Erickson	A Bateman (PhD)	Dr M Muñoz-Rojas (The University of Western Australia), Dr E Veneklaas (The University of Western Australia)	The use of soil amendments and alternative soil substrates to increase soil function and seedling recruitment in post-mining arid landscapes	2017 – 2021	<a href="#">174</a>
D Merritt, T Erickson	E Ling (MSc)	Dr A Guzzomi (The University of Western Australia)	Design and testing of novel seed processing equipment and methods to improve seed-based restoration	2018 – 2020	<a href="#">175</a>
D Merritt, T Erickson	M Masarei (PhD)	Dr A Guzzomi (The University of Western Australia)	Native seeding mechanisation to facilitate efficient large-scale restoration of degraded lands	2017 – 2021	<a href="#">175</a>
B Miller	E Cowan (PhD)	Dr J Fontaine (Murdoch University), Dr R Standish (Murdoch University)	Assessing ecological resilience of post-mining restoration: testing fire recovery across a restoration chronosequence	2019 – 2022	<a href="#">176</a>
B Miller, K Ruthrof	A Brace (PhD)	Dr A Hopkins (Edith Cowan University), Dr J Fontaine (Murdoch University)	Shifting soil fungal communities in response to fire and weed management in urban <i>Banksia</i> woodlands	2019 – 2022	<a href="#">176</a>

DBCA Officer	Student	Academic	Project Title	Duration	Page
B Miller, D Merritt	R Miller (PhD)	Dr J Fontaine (Murdoch University), Prof J Enright (Murdoch University)	Ecologically tolerable fire regimes for key <i>Banksia</i> woodland plant species	2015 – 2019	176
B Miller, D Merritt	R Tangney (PhD)		Fire intensity, seasonal variation and seeds traits may influence seed fates in <i>Banksia</i> woodlands	2015 – 2020	177
K Ottewell, C Lohr, M Byrne	A Cooke (MSc)	Dr J Kennington (The University of Western Australia)	The social structure of a reintroduced population of boodies ( <i>Bettongia lesueur</i> ) at Matuwa, Western Australia	2019 – 2020	177
R Palmer	A Johnson (MSc)	H Moore, P Withers (The University of Western Australia)	Individually identifying feral cats to investigate population densities and trends in the Pilbara, Western Australia	2020 – 2020	178
R Palmer	H Abdi (BSc Honours)	Dr S Tomlinson (Curtin University), Dr B Bateman (Curtin University)	Testing of methods to exclude northern quolls ( <i>Dasyurus hallucatus</i> ) and other non-target species from soft-catch leg-hold traps set for feral cats in the Pilbara.	2019 – 2019	178
A Pinder	M Rahman (PhD)	Dr J Chaplin (Murdoch University)	Taxonomy and evolutionary history of <i>Australocypris</i> giant ostracods from Australian salt lakes	2019 – 2022	179
A Pinder	A Lawrie (PhD)	Dr J Chaplin (Murdoch University)	Taxonomy, ecology and evolutionary history of the salt lake gastropod <i>Coxiella</i>	2019 – 2022	179
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K Ruthrof	T Rasmussen (BSc Honours)	Dr J Fontaine (Murdoch University), Dr L Walden (Murdoch University)	Regeneration of canopy species following drought-induced die-off in the Northern Jarrah Forest	2020 – 2020	181
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K Shepherd, T Macfarlane	N Dakin (PhD)	Dr M Ludwig (The University of Western Australia), Prof G Kadereit (Mainz University, Germany)	Evolution of C <sub>4</sub> photosynthesis in the genus <i>Tecticornia</i> at the anatomical and molecular levels	2017 – 2020	181
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K Trayler	N Stephens (PhD)	Dr K Warren (Murdoch University), Dr C Holyoake (Murdoch University), Dr P Duignan (University of Calgary)	Dolphin health - toxicogenomics and pathology investigations	2020 – 2022	185
K Trayler	A Saeed (PhD)	A/Prof M Hipsey (The University of Western Australia), Prof C Oldham (The University of Western Australia)	Identification of controls on the metabolism of the Swan-Canning Estuary using numerical modelling and high-frequency data	2018 – 2021	185
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A Wayne	M Taylor (PhD)	Dr K Bryant (Murdoch University), Dr N Armstrong (Murdoch University)	Survey methods and population estimates of the chuditch across its range	2020 – 2023	187
A Wayne	W Geary (PhD)	A/Prof E Ritchie (Deakin University), A/Prof D Nimmo (Charles Sturt University), Dr T Doherty (Deakin University), Dr A Tulloch (University of Sydney)	Modelling species interactions and other environmental factors in the Upper Warren	2019 – 2022	187
A Wayne	S Thorn (PhD)	A/Prof N Mitchell, Dr R Firman (The University of Western Australia)	The population and spatial ecology of the numbat in the Upper Warren	2018 – 2021	188

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S Wilson	D Ellis (PhD)	Dr C Fulton (Australian National University)	Habitat quality as a driver of epinepheline serranid productivity and replenishment	2018 – 2021	189
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## Student Project Reports



### Ecology of the feral cat in coastal heaths of the south coast of Western Australia

STP 2016-018

Scientist(s): D Algar

Student: S Comer (PhD)

Academic(s): Dr D Roberts (The University of Western Australia), Dr P Speldewinde (The University of Western Australia)

This part-time project is investigating habitat use, movement, dietary preferences and prey availability in important conservation reserves of the region. The relationship of landscape fragmentation to these factors is being examined, and builds on work completed through the South Coast Integrated Fauna Recovery Project and South West Fauna Recovery Project. The aim of this project is to provide information essential to optimising the effectiveness of control programs for this introduced predator in south coast ecosystems.

Collection of samples is now complete, with a further 30 feral cat stomach, tissue and samples from south coast reserves being analysed, including the use of stable isotope analysis to determine dietary preferences.



### Responses of southern boobooks to threatening processes across urban, agricultural and woodland ecosystems

STP 2017-052

Scientist(s): A Burbidge

Student: M Lohr (PhD)

Academic(s): Dr R Davis (Edith Cowan University)

The Australian boobook (*Ninox boobook*) is a cryptic owl that appears to be declining in south-west Western Australia. This project aimed to identify possible causes across a series of landscapes impacted differently by human activity.

A paper showing weak spatial genetic structuring and no evidence of genetic erosion associated with inbreeding in heavily fragmented landscapes, probably a consequence of the dispersal capacity of boobook offspring and their ability as habitat and dietary generalists to make use of highly altered landscapes, has been accepted

for publication in *Emu - Austral Ornithology*. A paper showing that artificial nest box supplementation does not appear to affect boobook occupancy in fragmented habitats has been submitted for publication in *Wildlife Research*. Another paper, showing that most risk factors previously implicated in increased risk of *Toxoplasma* infection did not show significant correlations with observed seropositivity in boobooks, has been submitted for publication in *Emu - Austral Ornithology*.



## Ecology and conservation biology of the night parrot

STP 2017-051

Scientist(s): A Burbidge

Student: N Leseberg (PhD)

Academic(s): A/Prof R Fuller (University of Queensland), Dr S Murphy (Australian National University), Dr J Watson (University of Queensland)

The night parrot (*Pezoporus occidentalis*) is an enigmatic ground dwelling parrot that is believed to occur across arid Australia but has rarely been seen as it is nocturnal and occupies remote habitat. Recent discovery of birds in Queensland and Western Australia has provided an opportunity to study the ecology and biology of this species at several sites across the Australian arid zone. Little is known about habitat use and ecology of this bird so studies are being undertaken to improve recognition and management of potential habitat.

This project has focused on the Queensland population. Progress has been made to improve software recognisers for recorded calls. The very short duration of night parrot calls mean they are very difficult to detect (visually or by software) in recordings, which form the basis for the only known effective survey/monitoring method. Current analyses of historical occurrences will assist in planning future survey work.



## Assisted colonisation of the western swamp tortoise (*Pseudemydura umbrina*): the role of energy requirements in translocation decisions

STP 2020-061

Scientist(s): M Byrne

Student: B Nordstrom (PhD)

Academic(s): A/Prof N Mitchell, S Jarman (The University of Western Australia)

The western swamp tortoise (*Pseudemydura umbrina*) is endemic to south-west Australia and occupies seasonal wetlands whose hydroperiods are shortening due to declining rainfall. Trial translocations 300-400 kilometres south of their current habitat began in 2016 to test whether *P. umbrina* can grow in cooler climates where hydroperiods are likely to be more suitable in the future. Such intentional translocations of a species outside their indigenous range to mitigate climate change is known as assisted colonisation. Results of the recent assisted colonisation trials were mixed, and suitable food availability was thought to be a key component of a successful short trial in the east Augusta region. The main aim of this research is to understand whether energy requirements of the western swamp tortoise can be met in cooler climates. This will be achieved by: 1) developing novel environmental DNA methods to detect the species and determine their diet in new habitats; 2) documenting foraging behaviour in a southern wetland in relation to water temperatures and prey availability; and 3) linking metabolic processes and food intake to predict long-term rates of growth and reproduction of individuals released into new environments. This project will provide greater certainty on whether southern wetlands can provide viable habitat for this critically endangered species in the near future.

Work has commenced in the east Augusta region to evaluate candidate wetlands for a third assisted colonisation trial planned for 2021. Wetlands are being sampled for water quality, and DNA metabarcoding methods are being used to characterise wetland species diversity and will be contrasted with traditional physical sampling. In addition, water and sediment samples have been collected from the field and the captive-breeding facility at Perth Zoo to test eDNA detection methods for *P. umbrina*.





## Adaptive and phylogeographic variation in sympatric parasitic and non-parasitic species in Western Australia

STP 2017-030

Scientist(s): M Byrne  
 Student: S Walters (PhD)  
 Academic(s): Dr P Nevill (Curtin University), A/Prof G Wardell-Johnson (Curtin University), Dr T Robinson (Curtin University)

This project aims to improve our understanding of local adaptation and phylogeographic patterns in parasitic and non-parasitic plant species' important for mine site restoration in Western Australia. Range-wide sampling and next generation sequencing technologies will be utilised to examine: signals of adaptive genetic variation; and phylogeographic patterns for four plant species endemic to Western Australia. The research will determine whether generalist and limited host-specific parasitic species have similar adaptive variation and phylogeographic patterns compared to sympatric non-parasitic plants. Species distributions will be extrapolated using spatial modelling to predict patterns of adaptive genetic variability across the landscape and develop a tool to guide seed sourcing for restoration.

Analysis of adaptive variation and phylogeographical patterns has been completed for all four species. A stronger genomic signal of selection was observed in the host-specific parasite (*Amyema gibberula* var. *tatei*) compared to its primary host species (*Hakea recurva* subsp. *recurva*), but this was not observed for the generalist parasite (*Nuytsia floribunda*) compared to a co-occurring autotroph (*Melaleuca rhapsiophylla*). Patterns of local adaptation to climate show adaptive genomic diversity in parasitic species to be associated more with temperature, rather than precipitation variables, while the opposite is observed for the non-parasitic species. Phylogeographical analysis showed the parasitic plants to have lower genetic diversity and greater population structuring than co-occurring autotrophic plants. Spatial modelling has been used to predict patterns of adaptive genetic variability in all four species and the development of tool to guide seed sourcing for restoration is currently underway.



## *Reedia spathacea* F. Muell.: a study of phylogeography, population structure and co-occurrence

STP 2017-029

Scientist(s): M Byrne  
 Student: J Bruce (MSc)  
 Academic(s): Dr A Koenders (Edith Cowan University), Prof P Horwitz (Edith Cowan University), Dr K Lemson (Edith Cowan University), Dr Q Burnham (Edith Cowan University)

*Reedia spathacea* (Cyperaceae) is a species of sedge found in the peat swamps of the Jarrah Forest and Warren biogeographical regions. The growth habit is particular to the species and it has apical meristems and above ground rhizomes protected by retained leaf sheaths with lateral roots that act as a means of clonal dispersal. Knowledge of morphology and reproductive strategy remain poorly known. The species is currently listed as critically endangered and occurs in ecological communities that are threatened by feral pig damage, increased fire frequency, weed invasion, fluctuations in water quality and changes to land use, such as groundwater extraction and land clearing. This study aims to evaluate the morphology and ecology of the species and to determine its genetic structure and historical biogeography. Microsatellite DNA analyses will be used to determine population genetic structure of *R. spathacea* and chloroplast sequence data will be used to determine the evolutionary history.

Molecular clock dating with the chloroplast DNA markers *rbcL*, *trnL* and the *trnL-F* intron has provided strong evidence that the lineage *Reedia* is Gondwanan, and that *Reedia* itself diverged from its sister taxa during the increased aridification of the southern portion of the Australian continent approximately 20 million years ago. Haplotype networks of the chloroplast markers *psbE-petL* and *trnS-trnG-trnG* show little variation and shared haplotypes between populations. The microsatellite analyses detected 13 genetic groups among the 15 geographic populations sampled. Significant departure from Hardy Weinberg Equilibrium was found across

all populations indicating the presence of inbreeding, with no recent bottlenecks detected by either a sign or Wilcoxon sign-rank test for any population under any mutation model. Genetic differentiation between populations was moderately high and sexual reproduction appears to be more important to recruitment than clonality. These data indicate a previously more wide-spread and panmictic distribution for *Reedia* that has now become a series of isolated populations.



### ***Conospermum undulatum*: insights into genetics and ecology of an endangered species**

STP 2017-028

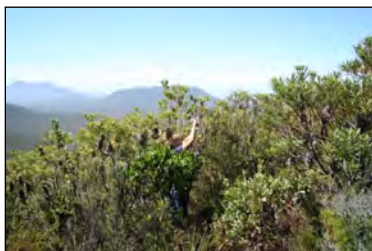
Scientist(s): M Byrne

Student: N Delnevo (PhD)

Academic(s): Dr E van Etten (Edith Cowan University), Prof W Stock (Edith Cowan University)

Anthropogenic loss and fragmentation of natural habitats has been increasing during the last 60 years and is now at unprecedented levels, making land use change one of the most important drivers affecting biodiversity. *Conospermum undulatum* is endemic to south-west Western Australia, a global biodiversity hotspot. Significant reductions in population size, connectivity, area and floral display of remnant patches are likely to constrain the reproduction of this species by altered plant-pollinator interactions and expression of inbreeding depression because of reduced gene flow between unrelated individuals. This project will investigate the reproductive biology and genetic diversity in the species to inform recovery actions to enhance the future persistence of *C. undulatum* by means of an improved understanding of factors that constrain both its reproduction and its adaptation ability over the long-term.

The pollination study showed that cross-pollination by hand produced a ten-fold increase in seed production compared to natural pollination. Increased seed set using pollen sourced from different populations showed that small populations are producing approximately 50 percent less seeds than what they are able to produce via inter-population cross-breeding due to the combined effects of pollen limitation and reduction in compatible mate availability. Genetic analysis of populations using 19 microsatellite loci revealed weak genetic structure, and levels of genetic diversity and differentiation indices indicate high levels of gene flow prior to fragmentation. These results suggest that habitat fragmentation may result in patches that are too small and isolated to be attractive for pollinators and to allow a long-term population viability based on reproduction by seed. Pollinator assessment showed *C. undulatum* has evolved pollen with resistance to the usually negative effect of ant secretions on pollen grains, with ants providing effective pollination services to this threatened species.



### **Mating systems, reproductive output and progeny fitness of translocated plant populations compared to wild populations**

STP 2017-027

Scientist(s): M Byrne, C Yates

Student: R Dillon (PhD)

Academic(s): Prof M Waycott, Dr R Standish (The University of Western Australia)

Translocations are a key conservation recovery action for threatened plant species and determining their success is an important aspect of ongoing management. This project is investigating the success of translocation in *Banksia brownii* and *Acacia rheticocarpa* and aims to: (1) compare the mating systems and genetic diversity of translocated populations with wild populations; (2) determine how reproductive output and progeny performance of translocated populations compares to wild populations; and (3) assess the efficacy of using measures of mating system parameters, genetic diversity and reproductive potential to better understand translocation success. The findings have a number of potential implications for not only assessing long term translocation success, but for also improving translocation design and establishment technologies.

Mating system and genetic diversity analysis has been completed on one translocated *B. brownii* population

and four wild populations to benchmark mating system performance and genetic diversity in the translocated population. Reproductive output and pollination studies are complete and data has been combined with mating system and genetic diversity data to produce a draft manuscript for publication. Fitness trait studies are ongoing in a common garden experiment involving 500 seedlings to assess the performance of the translocated population in comparison to wild populations. Reproductive output measurements, seed and adult leaf material were collected from three natural and two translocated populations of *Acacia rhotinocarpa*, to benchmark genetic diversity and reproductive output in the translocated populations. Fitness traits were measured for 800 seed and the subsequent seedlings from two wild and two translocated populations of *A. rhotinocarpa* and the glasshouse fitness study is now complete. Leaf samples were collected from the 800 seedlings and DNA extracted is complete. Microsatellite marker selection for this species is underway.



### Factors affecting the success of threatened flora translocations

STP 2017-026

Scientist(s): M Byrne, C Yates

Student: L Monks (PhD)

Academic(s): Dr R Standish (The University of Western Australia)

The aim of this study is to investigate factors affecting success of plant translocations, to inform future translocations and help prevent the extinction of plant species.

The meta-analysis investigating factors influencing success of past plant translocations in Western Australia is in the final stages with model refinement. Data analysis of genetic diversity values and mating systems parameters of translocated compared to the wild, source populations of *Lambertia orbifolia* has been completed and a paper describing the work is in draft. Preliminary analysis of monitoring data from translocated and wild populations of *Acacia cochlocarpa* subsp. *cochlocarpa* has commenced to inform the development of a Population Viability Analysis model to determine the trajectory of translocated populations compared to wild populations. A glasshouse cross pollination study of *Schoenia filifolia* has been completed and analysis of fitness traits is in progress, to evaluate whether the genetic composition of the founder populations contributes to translocation success.



### Tracking seagrass condition: development and application of novel molecular biomarkers

STP 2020-005

Scientist(s): J Cosgrove, K Trayler

Student: M Jung (PhD)

Academic(s): Dr M Fraser (The University of Western Australia), Dr BC Martin (The University of Western Australia)

Seagrass communities are under threat at a global scale, yet molecular physiological responses of seagrass to key stressors remains largely unknown. Here, novel molecular biomarker techniques such as metabolomics and proteomics are being applied on Western Australian seagrasses using a combination of field and mesocosm experiments.

*In situ* experiments will be used to assess both the metabolic and proteomic response of *Halophila ovalis* and *Halodule uninervis* along environmental gradients in the Swan-Canning estuary (year 1 and 2) and Shark Bay (year 3), respectively. Metabolomic analyses of leaf samples have recently been conducted and results will be related to sediment, seagrass and environmental data supplied by DBCA annual monitoring and additional water column dissolved oxygen data collected with loggers at each of the six Swan Canning study sites.



## The influence of invasive predators and fire regimes on northern quolls in the Pilbara

STP 2017-045

Scientist(s): J Dunlop

Student: H Moore (PhD)

Academic(s): Dr D Nimmo (Charles Sturt University), Prof D Watson (Charles Sturt University), Dr L Valentine (The University of Western Australia)

The study aims to explore the hypothesis that northern quolls (*Dasyurus hallucatus*) previously utilised a range of different habitat types in their movement and foraging activities in the Pilbara, but pressure from predators (feral cats, foxes and dingoes), in conjunction with other threats such as grazing and fire, have restricted their occurrence to the more protected rocky habitat.

Between September 2017 and March 2019, 1,928 independent northern quoll detections were recorded using remote sensor cameras across 23 study landscapes in the Pilbara. From these detections, a total of 156 individual northern quolls were identified. Results suggest that: (1) camera traps are likely to be a more cost effective method of monitoring northern quolls when compared to live traps; (2) camera orientation (vertical or horizontal) has little impact on northern quoll detectability; (3) in addition to northern quolls, downward facing cameras have useful applications for monitoring other predators, such as perenties (*Varanus giganteus*); and (4) the size, shape and composition (vegetation cover, den availability) of granite outcrops are all important predictors of northern quoll occurrence in the Pilbara, along with the structure of surrounding vegetation, and spatial activity of the feral cat. Analysis that explores northern quoll fine scale habitat use using data collected from GPS collars is now underway.



## Ecology of flatback turtles (*Natator depressus*) at a coastal foraging ground, Western Australia

STP 2020-025

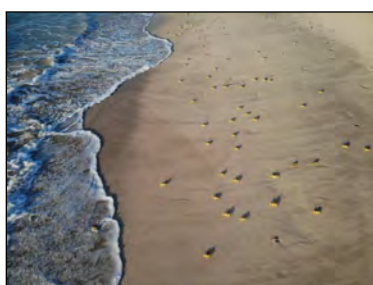
Scientist(s): S Fossette-Halot

Student: J Hounslow (PhD)

Academic(s): Dr AC Gleiss (Murdoch University)

This project aims to improve our understanding of flatback turtles using bio-logging tools such as daily diaries and animal-borne video cameras that collect accelerometry data, orientation data and swimming performance data. Data will be used to analyse the turtles' fine-scale vertical and horizontal movements at a recently discovered foraging ground. The anticipated outcome of this project is to assess how flatback turtles might be impacted by anthropogenic disturbances at their foraging grounds.

Three field trips to Roebuck Bay were completed. Twenty-four flatback turtles were tagged, 14 cameras and 10 daily diaries were deployed that collected 43 days of continuous diary data and 57 hours of video. A paper describing how animal-borne video from a sea turtle revealed novel anti-predator behaviour has been submitted to the journal *Ecology*. Analyses of turtle diving behaviour is under way using state-of-the-art machine learning algorithms to identify dive functions.



## Understanding predator-prey interactions between ghost crabs and marine turtles for better management of an endangered species

STP 2020-024

Scientist(s): S Fossette-Halot, S Whiting

Student: C Avenant (PhD)

Academic(s): A/Prof G Hyndes (Edith Cowan University)

This project will examine predator-prey interactions between ghost crabs and hatchling sea turtles on the Ningaloo coast to better conserve these endangered turtle species and manage a native predator. It will provide critical information for the management of marine turtles and their rookeries and help fill a gap in the scientific literature regarding the potential impact of native ghost crabs on turtle eggs and hatchling survival. This will help assess vulnerability of different nesting sites and determine if there is need for human intervention.

Four field trips were successfully completed to Gnaraloo Bay and Cape Range National Park with a total of 68 days in the field. Over 4,000 ghost crab burrows were counted and their diameters measured for statistical analysis. A total of 613 ghost crabs were collected, from which 193 were dissected and gut contents analysis was completed on 133 individuals. Eight loggerhead turtle nests were closely monitored and 272 emerging loggerhead hatchlings were recorded on video to determine survival and predator impacts.



### Predicting the vulnerability of flatback turtle rookeries to a changing climate

STP 2019-047

Scientist(s): S Fossette-Halot  
 Student: M Gammon (PhD)  
 Academic(s): A/Prof N Mitchell, G McGrath

This project aims to predict the vulnerability of flatback turtle rookeries on the North West Shelf to increasing sand temperatures, sea level rise and increased storm frequency. It will provide critical information for the management of marine turtles and their rookeries and help assess vulnerability and long-term conservation value of different nesting sites and determine if there is need for human intervention.

Two field trips were successfully completed. Six egg clutches were collected from Cemetery Beach at Port Hedland and incubated in the lab to identify this population's pivotal temperature and transitional range of temperatures for sex determination. Over 100 blood plasma samples were collected from these embryos to trial a new method of determining hatchling sex from blood samples. Methods were trialled on Thevenard Island to develop a mechanistic model of the microclimate experienced by each embryo within a nest. A literature review was submitted to *Frontiers in Ecology and Evolution*.



### Foraging ecology and energetics of green turtles in the Ningaloo coast world heritage area

STP 2017-050

Scientist(s): S Fossette-Halot  
 Student: J Stubbs (PhD)  
 Academic(s): Dr M Vanderklift (The University of Western Australia),  
 A/Prof N Mitchell

This project is part of the Ningaloo Outlook CSIRO-BHP research partnership and is investigating green turtle foraging ecology and energetics. This outcome will be achieved by: (1) investigating the diet and variation in diet between size/age classes using stable isotope analysis; (2) describing the movement of foraging and nesting green turtles using satellite tags; and (3) using dynamic energy budget (DEB) modelling to investigate allocation to growth and reproduction throughout the lifecycle.

Data analysis for the stable isotope work was completed and the DEB simulation modelling was finalised. A thesis was submitted and classified as passed with minor corrections. The project findings were presented at the Ningaloo Outlook Symposium in February 2020 and a manuscript was accepted for publication in *Ecological Modelling*.



## A cost benefit analysis for the collection of reef fish density data with a micro remote operated vehicle versus SCUBA divers.

STP 2019-043

Scientist(s): J Goetze  
 Student: LH Hellmrich (BSc Honours)  
 Academic(s): Prof E Harvey (Curtin University)

A common method for sampling shallow water reef fish populations is Underwater Visual Census (UVC), where a diver collects information on the abundance, composition and length of fishes within a known sample unit. Major limitations with UVC techniques are inter-observer variability and a lack of accuracy and precision with length and distance estimates. Diver operated underwater stereo-video (stereo-DOV) was developed to overcome these challenges. While stereo-DOV overcomes some of the biases associated with UVC, this method still relies on divers. Occupational safety limits associated with SCUBA diving means that many marine habitats cannot be sampled in this way. Due to such constraints, research has focused on the development of fishery independent sampling techniques that do not rely on the use of SCUBA. One alternative is Remote Operated Vehicles (ROVs), which can operate for extended periods of time and at depths beyond 2,500m. Recently, micro ROVs have become increasingly available as a cost-effective sampling tool. By equipping a micro ROV with a lightweight stereo-video system, it is now possible to survey fish assemblages using UVC sampling methods. This project aims to compare the data collected with a micro ROV equipped with a stereo video system to those collected by a SCUBA diver as well as compare and contrast cost efficiencies of each method for monitoring finfish.

ROV and stereo-DOV surveys have been completed inside and outside of the Maud Sanctuary Zone in Ningaloo Marine Park. Video and statistical analysis have been completed and a draft manuscript is being prepared for publication in a peer reviewed journal.



## Integrated study of shallow and deep-sea fish communities status and their main stressors in a highly dynamic Galapagos seascape

STP 2019-042

Scientist(s): J Goetze  
 Student: ER Rastion (PhD)  
 Academic(s): Prof E Harvey (Curtin University)

In 2016, Galapagos National Park authorities increased the surface area of full no-take areas in the Galapagos Marine Reserves from 0.8% to 33%. However, no specific measures (e.g. seasonal closure, maximum or minimum size limit, quotas) have been implemented to mitigate the downward trends observed in fisheries targeted species outside of the reserve. As a consequence, new fish resources are being sought in deeper waters. The project aims to assess the effect of the Galapagos Marine Reserve, changes in fisher effort and environment on fish assemblages in the Galapagos. The results of conservation approaches in the Galapagos can be compared and contrasted to Western Australia to inform and potentially improve on the monitoring and conservation of marine fishes in both locations.

All data has been collected and is currently being analysed. A manuscript examining the ability of diver operated stereo-video (stereo-DOVs) to characterise reef fish spawning aggregations, has been accepted by the journal *Estuarine, Coastal and Shelf Science*. Stereo-DOVs are the primary method used to monitor finfish in Western Australia's marine parks and this study shows that diver operated stereo-video system produce accurate measures of fish length, density and reproductive behaviours, providing an easily repeatable and non-destructive tool for the monitoring of spawning events.



## A comparison of stereo-BRUV, diver operated and remote stereo-video transects for assessing reef fish assemblage

STP 2019-041

Scientist(s): J Goetze  
 Student: KS Schramm (MSc)  
 Academic(s): Prof E Harvey (Curtin University)

Monitoring programs that aim to measure the diversity, abundance and biomass of fishes depend on accurate and reliable biological data to inform management. It is important to identify an appropriate sampling technique that provides a comprehensive assessment, while reducing associated biases in the data collection process. Advances in technology can provide new opportunities for collecting fish assemblage data, overcoming limitations and biases of existing methods. This project aims to compare the sampling abilities of four different, underwater stereo-video methods, two of which are relatively new methodologies (slow-towed stereo-video (STV) and remotely operated vehicle (ROV) fitted with a stereo-video), in a temperate reef system in Geographe Bay. This information can be used to inform monitoring and research programs on which methods are most effective for sampling fishes of varying life histories.

A manuscript has been accepted by the *Journal of Experimental Marine Biology and Ecology*, which demonstrates that ROV, DOV and tow techniques provide comparable estimates of temperate fishes, but BRUVs better represent predatory species often targeted by fishers. Analysis of a similar methodological comparison in tropical Western Australia waters is underway, with a draft manuscript being prepared for publication in a peer reviewed journal.



## Cyclone impact or natural variation? Assessment of damage on coral and fish in Kubulau District, Fiji by cyclone Winston

STP 2019-040

Scientist(s): J Goetze  
 Student: B Price (MSc)  
 Academic(s): Prof E Harvey (Curtin University)

Cyclones are a prominent feature force along the coast of northern Australia that can have a strong influence on coral reef communities. With a changing climate it is predicted that cyclones will increase in severity, increasing degradation of coral reefs and compromising the services they provide to coastal communities. In 2016, Fiji was impacted by category 5 tropical cyclone Winston, which at the time was the most severe cyclone recorded in the southern hemisphere. Ongoing monitoring using diver operated stereo-video, enabled the assessment of cyclone impacts on both coral reef habitat and fish assemblages, which will provide insights into the relationships between habitat and fish on reefs. This type of information can be used to inform recovery and sustainable management of habitat and fish stocks after a severe cyclone. Socioeconomic data was also collected, facilitating an assessment of how cyclones impact on coastal communities and how this relates to changes in ecosystem services post-cyclone.

A draft manuscript has been completed that describes the impacts of cyclone Winston on habitat and fish populations in Fiji. Despite a decrease in live coral cover, impacts to fishes varied spatially and were limited to obligate corallivores. Data on the socio-economic impacts of cyclone Winston and how this relates to the ecological changes has been collected and is currently being analysed.



## Conservation of elasmobranchs - ecology, public perception, and legal protections

STP 2019-039

Scientist(s): J Goetze

Student: MC Márquez (PhD)

Academic(s): Prof E Harvey (Curtin University)

Sharks and rays are identified as important ecological assets with a high research priority in a number of Western Australian marine parks, yet little is known about the importance of habitat (e.g. nursery grounds) or public perception and their influence on conservation success. The life history traits of many shark species, including large body size, slow growth, late maturity, and low fecundity, also makes them particularly vulnerable to over-fishing and other anthropogenic threats. Thirty-one percent of the world's sharks and rays are threatened with extinction and declines have led to an increased need for conservation and sustainable management. However, sharks play important ecological and socioeconomic roles and the consequences of population declines are not well studied. This research will identify nursery habitats and compare cultural beliefs and public attitudes towards sharks in areas where sharks are depleted (e.g. the coral triangle) to areas where they are relatively healthy (e.g. Western Australia). To understand the drivers of peoples perceptions of sharks, socioeconomic surveys will be implemented across a broad range of stakeholders in these regions.

A literature review describing the cultural perceptions of sharks and the influence this has on sustainable management has been completed and will be submitted to the journal *Conservation Biology*. This review is particularly relevant to Western Australia with insights into the role that public perceptions play in the implementation of shark management.



## Persistence of tropical herbivorous fish in temperate ecosystems and its impact on habitat-forming macrophytes

STP 2018-020

Scientist(s): T Holmes

Student: S Zarco (PhD)

Academic(s): Dr T Wernberg (The University of Western Australia), Dr T Langlois (The University of Western Australia)

This project aims to examine the impact that range expanding tropical herbivorous fish can have on temperate ecosystems by analysing the variability of their abundances, recruitment and consumption rates at different spatial and temporal scales in south-western Australia. The research will answer fundamental questions about the longer term persistence, and the impacts, of the most common tropical herbivorous fish group (family Siganidae) extending into high-latitude ecosystems, on temperate marine ecosystems in Western Australia.

Field work in the Perth metropolitan region has been completed and data have been analysed. The first paper from this work was published in the journal *Proceedings of the Royal Society Part B* and demonstrated that overwintering tropical herbivorous fishes accelerate detritus production in temperate ecosystems. A second paper has been provisionally accepted in the journal *Functional Ecology* and shows that tropical herbivores increase functional diversity in temperate fish assemblages, potentially having impacts on local benthic habitats.





## Does a restoration plant community trajectory track that of the soil biota through a 30-year post-mining chronosequence?

STP 2019-065

Scientist(s): S Krauss, B Miller  
 Student: Ms L Ducki (BSc Honours)  
 Academic(s): Dr R Standish (Murdoch University)

Plant communities have been the primary focus of ecological restoration initiatives. However, the integration of the soil microbiome is an increasing focus of restoration practice. The interdependent nature of the above- and below-ground biological environments has led to assumptions that reciprocal shifts in community compositions will occur in response to disturbance and restoration. Here, a 30-year restoration chronosequence of vegetation development was compared with that of the below-ground assemblages of bacteria and fungi, identified using eDNA methods.

Similarities between restoration trajectories of fungal and vegetation assemblages were found, though both remained distinct from reference Jarrah forest compositions. In contrast, soil bacterial assemblages in restored Jarrah forest re-assembled rapidly, with substrate depth being a greater driver of composition than vegetation. These findings add to a body of literature that acknowledges the rich diversity of the below-ground microbial community, and the potential for their use as predictors of restoration trajectories.



## Genetic consequences of bird pollination for the catspaw *Anigozanthos humilis*

STP 2019-064

Scientist(s): S Krauss  
 Student: J Kestel (BSc Honours)  
 Academic(s): Dr P Grierson (The University of Western Australia), Prof S Hopper (The University of Western Australia)

The behaviour of pollinators has consequences for the plants they pollinate. Highly mobile nectar-feeding birds often display behaviour that results in more pollen carryover than insect pollinators, which is predicted to result in frequent outcrossing and high paternal diversity for bird-pollinated plants. This prediction was tested by quantifying mating system parameters and bird-visitation in the catspaw *Anigozanthos humilis* subsp. *humilis*.

Outcrossing rates were high but significantly less than one, and correlated paternity was surprisingly high. Bird visits to flowers were infrequent, most of which were by the western spinebill. Pollen counts from 30 captured honeyeaters revealed that *A. humilis* comprised 0.3 percent of the total pollen load. Low visitation rates and low pollen loads of floral visitors have led to the low mate diversity observed.



## Conservation genetics of the critically endangered *Styphelia longissima*

STP 2019-005

Scientist(s): S Krauss  
 Student: W Thomas (BSc Honours)  
 Academic(s): Dr P Grierson (The University of Western Australia)

*Styphelia longissima* (Ericaceae) is a critically endangered shrub located near Eneabba and is represented by a single small and isolated population. Levels of genetic variation and its spatial structure, mating system parameters and patterns of pollen dispersal were examined.

Allelic richness and expected heterozygosity were higher than predicted. Outcrossing rate was moderate, and biparental inbreeding was pronounced. Pollen dispersal by insects was highly restricted, with 95 percent of matings occurring less than 7m. This study provides baseline data on genetic diversity, mating system and

pollen dispersal for future monitoring of *S. longissima*. A manuscript has been submitted for publication.



### **A genecological assessment of seed sourcing strategies for plant community restoration under environmental change.**

STP 2019-003

Scientist(s): S Krauss, J Stevens

Student: B Mirfakhraei (PhD)

Academic(s): Dr E Veneklaas (The University of Western Australia)

This research aims to provide a comprehensive test of the influence of climatic and edaphic variation on the performance of genotypes from multiple provenances, to identify best-practice seed sourcing for restoration. Although many strategies for seed sourcing have been proposed, there are few empirical tests of different strategies. In this project, multiple genetic provenances of *Banksia menziesii*, a restoration priority plant species on the Swan Coastal Plain, will be tested in post-mining rehabilitation field sites, as well as glasshouse growth trials where environmental parameters will be modified. In addition, physical, chemical and biological properties of soils from these multiple source sites will be assessed and compared to the performance of seeds sourced from these sites.

Soil microbiome community and physicochemical analysis from remnant populations of *Banksia menziesii* across its range is completed. These results show significant correlations between soil microbiome, soil physicochemical and climate distances. The glasshouse experiment of provenance performance under different water treatments is completed with analysis of results in progress.



### **Novel consequences of bird pollination in the kangaroo paw *Anigozanthos manglesii***

STP 2019-002

Scientist(s): S Krauss

Student: B Ayre (PhD)

Academic(s): Prof S Hopper (The University of Western Australia)

Pollinator services underpin the function and sustainability of most terrestrial ecosystems. Optimal foraging theory predicts that the majority of pollen dispersed by animals will be among the nearest neighbours. However, pollen carryover, and differences in the movement behaviour between vertebrates and invertebrate pollinators, will affect paternity in natural plant populations. The South West Australian Floristic Region has the highest incidence of vertebrate pollination worldwide. Recent studies suggest that almost near random mating may occur in populations of plants pollinated by highly mobile nectar feeding bird species. This research project aims to address the consequences of bird pollination on mating, spatial genetic structure, and fitness in kangaroo paws (*Anigozanthos manglesii*).

Controlled hand pollinations showed that selfing and nearest neighbour mating results in inbreeding depression and a decline in reproductive success with increasing mate distance. These results suggest an optimal outcrossing distance among near neighbours in natural populations. Paternal diversity and pollen dispersal following bird-pollination was 10 times greater than that following pollination by insects. Introduced honeybees are frequent visitors to flowers but ineffective pollinators, and therefore native nectar-feeding birds are critical for effective pollination of *A. manglesii*. Three papers have been published in *Applications in Plant Sciences*, *Annals of Botany* and *Australian Journal of Botany*.



## Evolution and conservation consequences of bird pollination: an ecological and genetic study of mating, pollen dispersal and recruitment in *Eucalyptus caesia*

STP 2019-001

Scientist(s): S Krauss

Student: N Bezemer (PhD)

Academic(s): Prof S Hopper (The University of Western Australia)

Compared to other regions around the globe, the South West Australian Floristic Region has an exceptionally high incidence of plant species that are predominantly pollinated by vertebrates, with approximately 2,000 species pollinated by birds. The behaviour of these birds suggests unique genetic consequences for the plants they pollinate. A combination of genetic techniques and field experiments with *Eucalyptus caesia* were used to examine three critical issues in pollination ecology and reproductive biology: (1) the relative contribution of native and introduced animals to pollen dispersal in plants adapted for bird pollination; (2) whether genetic factors such as heterozygosity and sibling relatedness influence seedling fitness; and (3) the consequences of bird pollination in range-wide genetic diversity.

A comprehensive population genetic analysis demonstrated low genetic diversity, extensive clonality and strong population genetic differentiation. Natural recruits and common garden experiments showed no evidence for inbreeding depression, suggesting that purging of genetic load as well as individual longevity explains the persistence of woody perennial plants endemic to granite outcrops. Pollinator experiments showed that bird-pollination increases paternal diversity above that of insect pollination in some populations, suggesting that insects may be effective pollinators in some populations but ineffective in others. Results have been published in a thesis and four peer-reviewed papers.



## Resource competition between co-existing threatened mammals in a predator-free enclosure in central Western Australia

STP 2019-035

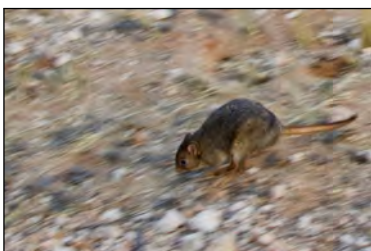
Scientist(s): C Lohr

Student: S Treloar (MSc)

Academic(s): Dr R Davis (Edith Cowan University), Dr A Hopkins (Edith Cowan University)

An understanding of resource requirements and inter-specific competition is essential when undertaking reintroductions, especially in fenced environments where dispersal and access to resources are limited. The burrowing bettong (*Bettongia lesueur*), or boodie, and the rufous hare-wallaby (*Lagorchestes hirsutus*), or mala, are both extinct in the wild on the Australian mainland and only occur on a few offshore predator-free islands and in several predator-free enclosures across Australia. Both species were reintroduced to an enclosure on the Matuwa Indigenous Protected Area in Western Australia. Little is known about the ability of these species to co-exist in a fenced environment and how they partition resources.

All fieldwork is complete. Genetic fingerprinting of mala for the purposes of estimating their abundance is complete. Genetic analysis of mala and boodie diet is on-going. Camera-traps did not detect competitive behaviour. Statistical analysis of the data is being undertaken.



## Reintroduced digging mammals and ecosystem restoration

STP 2018-082

Scientist(s): C Lohr

Student: B Palmer (PhD)

Academic(s): Dr L Valentine (The University of Western Australia), Prof R Hobbs (The University of Western Australia)

This project aims to explore the roles of digging mammals in ecosystem restoration by investigating: (1) how boodie warrens alter soils and vegetation communities; (2) whether the presence of digging mammals alters soils and vegetation communities at landscape scales; and (3) whether digging mammals disperse seeds in their scats. Field work for this project is being conducted in and around the predator-free enclosure on the Matuwa Indigenous Protected Area, and several other locations managed by other organisations.

All fieldwork for this project is complete. A review of faunal translocations in Australia has been accepted for publication. Laboratory and statistical analyses of soil nutrient profiles, and vegetation response to digging fauna is complete. Laboratory work on seed dispersal is complete. Two manuscripts are nearing completion and will be submitted for peer review.



### The effect of diet on the growth and reproduction of western swamp tortoise at Perth Zoo

STP 2018-124

Scientist(s): P Mawson

Student: G Wilkinson (MSc)

Academic(s): Prof P Horwitz (Edith Cowan University)

The western swamp tortoise (*Pseudemydura umbrina*) is a threatened species listed as critically endangered. The species occurs in only two natural populations at very low numbers. Establishing new populations entirely with wild caught tortoises is not feasible and captive breeding provides a source of animals for supplementation of wild populations and establishment of new populations. Following a review of the diet of the captive-breeding colony of western swamp tortoises, a second manufactured diet based on white-fleshed fish was developed to address concerns about low levels of omega-3 fatty acids in the 'traditional' red meat diet. For four years, approximately half the tortoises in the colony have been maintained on the original red-meat based diet and half on the white-fleshed fish diet. The project will determine whether there are any significant differences between the diets in hatchling and juvenile growth rates, weight loss associated with aestivation and female reproductive output (as determined by clutch size, egg mass and hatchling mass).

Analyses of the data on the growth rate of adult tortoises and each of the annual cohorts from hatchling to age 4 indicates that there was no significant difference due to diet. Analyses of the effect of diet on reproductive performance of the breeding females is under way and writing of the thesis has commenced.



### Within group social dynamics and pair-bonds in captive and rescued Javan gibbons

STP 2018-120

Scientist(s): P Mawson

Student: J Hale (MSc)

Academic(s): Dr N Malone (University of Auckland)

Javan silvery gibbons (*Hylobates moloch*) are a threatened species listed by the IUCN as endangered. Their decline is mainly attributed to habitat loss/fragmentation and the illegal wildlife trade. Rehabilitation and translocation are important conservation tools that allow rescued captive-held gibbons to be released into wild populations. However, this is a relatively new conservation strategy for gibbons and there are few published data on successful rehabilitation and release conditions. Appropriate captive management strategies are crucial to the success of the rehabilitation programs, for the management of animals during rehabilitation and for the management of captive-bred animals that can contribute to wild populations. This research aimed to investigate within-group social dynamics in captive and rescued Javan gibbons (*Hylobates moloch*).

A review of gibbon social dynamics, conservation status and conservation strategies was undertaken with a focus on rescue and rehabilitation programs in hylobatids and particularly Javan gibbons. Observation and analysis of within-group social dynamics and alternative group compositions in Javan gibbon was undertaken in two different contexts: social dynamics in a non-traditional grouping of captive Javan gibbons at Perth Zoo focusing on a family group that lacked an adult male and investigated sibling and mother-offspring relationships; and two non-traditional pairs of Javan gibbons at Aspinnall Foundation's Javan Primate Rehabilitation Centre.

These observed pairs were pairings of unusual and 'alternative' bonds. Both settings used observational data on affiliative and agonistic behavioural exchanges, as well as proximity interactions, as measures of gibbon pair-bonds and relationships. Observations were made of the social dynamics and interactions in these alternative groups that did not fit with traditional ideas of gibbon social systems. This study contributed to the growing literature on the flexibility of gibbon social dynamics by investigating gibbon social dynamics with an emphasis on 'beyond the pair-bond' behaviour. A full understanding of gibbon social dynamics is crucial for implementing effective husbandry and conservation practices.



### Evaluation of the welfare and reproductive biology of captive tigers using non-invasive conservation physiology techniques

STP 2018-117

Scientist(s): P Mawson

Student: J Scherpenhuizen (PhD)

Academic(s): Dr R Friere (Charles Sturt University)

Sumatran tigers (*Panthera tigris sumatraeare*) are a threatened species listed by the IUCN as critically endangered. Perth Zoo, along with all major zoos in Australia, are involved in a regional breeding program for Sumatran tigers. This project will develop and refine non-invasive assessment methods of tiger welfare and determine their effectiveness. Behavioural observations and analysis of faecal samples will be used to determine cortisol and sex hormone (testosterone, oestradiol and progesterone) levels.

All Sumatran tigers (*Panthera tigris sumatraeare*) faecal samples have been analysed to determine cortisol and sex hormone (testosterone, oestradiol and progesterone) levels. Behavioural observations have been collected and data are being analysed.



### Hindlimb paralysis syndrome in Carnaby's cockatoos

STP 2018-113

Scientist(s): P Mawson

Student: F Coiacetto (PhD)

Academic(s): A/Prof K Warren (Murdoch University)

Cockatoo hindlimb paralysis syndrome has been recognised as a new threat to Carnaby's cockatoos. Although a definitive diagnosis has not been obtained, the hypothesized etiology is an organophosphate-induced delayed-onset neuropathy. The syndrome may indicate that interaction between the cockatoos and inland agricultural practices are affecting this migratory species in ways that are, so far, poorly understood. The syndrome is confined to Carnaby's cockatoos and affects cockatoos regardless of gender or age, and is typically seen in the austral summer and autumn with a peak in presentations in February. The reason for the sudden emergence of the cockatoo hindlimb paralysis syndrome is unknown. This study aims to characterise and investigate the cause of Cockatoo Hindlimb Paralysis Syndrome (CHiPS) in Western Australian black cockatoos.

To date, necropsies have been performed on 17 CHiPS case animals and 14 control animals. No significant findings have been demonstrated with gross examination and histopathology; including serial sectioning of the brain, spinal cord, sciatic nerves, brachial plexus and multiple skeletal muscle bodies. The acetylcholine esterase assays that investigate acute organophosphate toxicosis have shown no significant findings. Initial results from an assay used to investigate delayed organophosphate neuropathy (NTE) in brain tissue has demonstrated a significant difference between CHiPS cases and control birds. The median brain NTE activity for control birds was 0.1172 mU/g of brain tissue compared to the median brain NTE activity of 0.0226 mU/g of brain tissue in CHiPS cases. Current work is focussed on validation of this assay (ensuring that the results are accurate and reproducible) and production of a reference interval for NTE in the brains of Carnaby's black cockatoos.



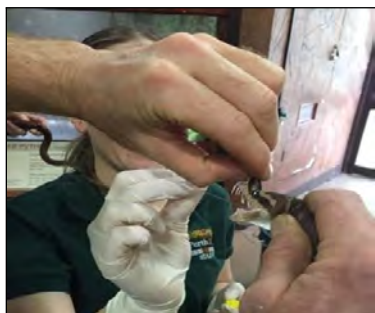
## The effect of incubation temperature on development rates of *Geocrinia alba* and *G. vitellina* frog embryos

STP 2018-110

Scientist(s): P Mawson  
 Student: E Hoffmann (PhD)  
 Academic(s): A/Prof N Mitchell

*Geocrinia alba* and *G. vitellina* have a restricted distribution and are listed as critically endangered and vulnerable. These frogs lay large clutches of eggs; however, the survival rate to adult frogs is low. Captive rearing of eggs to metamorphs is an effective means of providing supplementation of animals into the populations. Eggs clutches of both species are collected from the wild and metamorphs are raised and subsequently released. This project is part of the ongoing research and husbandry management to achieve regular and reliable captive breeding in both species.

Nine *Geocrinia alba* clutches, containing 115 eggs, and six *G. vitellina* clutches, containing 81 eggs, were collected from the wild. Eggs were successfully divided into minimum groups of four eggs and the split-egg clutches were randomly allocated to four temperature treatments. One hundred and four *G. alba* and 78 *G. vitellina* tadpoles successfully reached metamorphosis after 33-63 days, and there was a significant difference between temperature treatments and development times. Development rates were successfully acquired for temperatures between 15.5° C and 21.1° C (*G. alba*) and 17.3° C and 21.1° C (*G. vitellina*), and can now be used to model both field development times for different climate scenarios and estimating the species' critical thermal maximum.



## The prevalence of arenavirus, bornavirus, nidovirus/coronavirus, sunshinevirus and ferlavirus in captive and wild populations of Stimson pythons, pygmy pythons and carpet pythons

STP 2018-105

Scientist(s): P Mawson  
 Student: K Wood (PhD)  
 Academic(s): Dr T Hyndman (Murdoch University), A/Prof K Warren (Murdoch University), Dr S Vitali (Murdoch University)

The field of reptile virology is continually evolving with the discovery of novel reptile viruses; however, the importance and implications of these viruses are yet to be determined and the prevalence in both captive and wild populations is unknown. This project will investigate the prevalence of arenavirus, bornavirus, nidovirus/coronavirus, sunshinevirus and ferlavirus in both captive and wild populations of snakes. Three populations will be examined including Perth Zoo captive pythons, confiscated pythons (obtained by the department) and wild free ranging python species. The project aims to incorporate and build on data obtained from individuals housed at Perth Zoo, and samples from the wild to investigate whether these viruses are present in the wild population.

Over the last year the focus has largely been on sampling processing and diagnostic testing. All the Perth Zoo samples collected in 2017 have been tested for mycoplasma and most have been tested for nidovirus. The bornavirus PCR has required some troubleshooting so this testing has not yet been completed in its entirety, and the sunshinevirus PCR is also still pending. A retrospective analysis of the snakes which have been tested historically in the Perth Zoo collection has been completed.



## Predicting effects of climate change and thinning on growth, health and water yield of jarrah and karri stands using individual-based modelling

STP 2018-081

Scientist(s): R Mazanec

Student: K Bhandari (PhD)

Academic(s): Dr E Veneklaas (The University of Western Australia), Dr M Renton (The University of Western Australia)

The jarrah (*Eucalyptus marginata*) and karri (*Eucalyptus diversicolor*) forests of south-west Western Australia are important sources of timber, wildlife habitat and water. However, as climate changes, issues of forest productivity, tree health and mortality, and water yield need to be addressed. Individual-based modelling (IBM) is an ecological modelling approach that represents individuals within populations or communities, and the interactions between them, with a relatively high level of detail and complexity. This study aims to develop an IBM of tree growth in water limited environments, to parameterise the model for jarrah and karri and to predict the impact of tree thinning on timber production, tree health and mortality and water yield using time series data collected from 1965 and 1992, respectively.

For both species, thinning has a positive impact on growth with stand growth optimised at intermediate densities (10-20 m<sup>2</sup> ha<sup>-1</sup>) over multi-decadal time periods, consistent with findings from previous studies. Thinning also influences allometry of stem diameter with height, ratio of height and diameter, crown width and bark thickness. Linear IBM for diameter growth prediction have been developed for jarrah and karri that predict stem diameter growth based on initial diameter, initial height, size and distance of the nearest neighbours using competition indices. Four manuscripts have been prepared for publication, and a further manuscript reporting growth response of marri to thinning is undergoing internal review.



## The impacts of severe wildfire on the interactions among regenerating vegetation, fungi and small foraging marsupials in south-west Australia

STP 2016-016

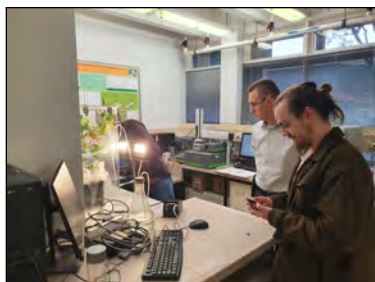
Scientist(s): L Mccaw

Student: H Etchells (PhD)

Academic(s): Dr P Grierson (The University of Western Australia), Dr A O'Donnell (The University of Western Australia)

This project seeks to enhance understanding of the ecological response of a variety of vegetation types to bushfire, focusing on the large O'Sullivan fire of February 2015. The study is examining the response of vegetation and fungal community composition to different levels of fire severity across four vegetation types (tall open eucalypt forest, open eucalypt forest, *Melaleuca/Allocasuarina* forest, *Banksia/sedge* heathland).

Fire severity has been determined from remotely sensed imagery. Field data have been collected at 48 sites and include details of overstorey composition and crown condition, seedling germination and survival, and understorey plant composition. Fungal community composition was determined using DNA extracted from soil samples, amplifying the fungal ITS2 region, to estimate relative abundance of fungal taxonomic entities. A paper reporting on the response of overstorey trees and understorey floristic composition to varying levels of fire severity was published in *Forest Ecology and Management*. Fungal responses to fire are currently being analysed and prepared for publication.



## The dynamic demography of water ages our trees are using

STP 2020-017

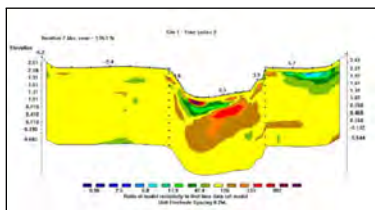
Scientist(s): G McGrath

Student: Mr L McCauley (MSc)

Academic(s): Associate Professor S Thompson (The University of Western Australia), Dr G Skrzypek (The University of Western Australia), Dr E Veneklaas (The University of Western Australia)

This project will conduct an experiment to test whether measurement of water isotopes in conjunction with the application of a numerical hydrological model can determine the distribution of ages (time since rainfall) of water transpired by plants. If successful, the method can be applied to better understand eco-hydrological functioning of plants. Potential applications include quantifying ecosystem-scale water use dynamics in eddy-covariance experiments, assessing effects of forest thinning or identifying dominant sources of water used by plants in threatened ecosystems like Ashfield Flats Reserve.

Seedlings were selected and grown in experimental pots, soil physical and hydraulic properties have been measured, and experimental design and design modelling of the pot hydrology was completed. A trial run of the gas exchange equipment and its interconnectivity with a water isotope analyzer was undertaken. Development of modelling software is underway and collation of a database of rainfall isotope data has been made from the scientific literature.



## Resistivity Geophysics Assessment of Hyporheic Exchange

STP 2020-016

Scientist(s): G McGrath

Student: Mr J Barrett (MSc)

Academic(s): Associate Professor M Leopold (The University of Western Australia)

The hyporheic zone is the thin region beneath a stream where surface water interacts with the subsurface. Better characterisation of this zone helps understand the potential for urban drains to trap and process pollutant loads. This project applied a Electrical Resistivity Tomography (ERT) to image the hyporheic zone of the Chapman Street Drain at Ashfield Flats Reserve.

Geophysical and in situ measurements were conducted before, during and after two rainfall events. Pore-water sampling showed hyporheic exchange occurred at a sandy site to a depth of 30 cm and was insignificant at a site with higher clay contents. Geophysics was able to image the spatial distribution of sediments; however, the observed hyporheic zone changes in resistivity were too weak to be resolved by ERT. The results suggest that resistivity may be better suited to characterising the spatial distribution of sediment properties that are conducive to hyporheic exchange.



## The use of soil amendments and alternative soil substrates to increase soil function and seedling recruitment in post-mining arid landscapes

STP 2019-024

Scientist(s): D Merritt, T Erickson

Student: A Bateman (PhD)

Academic(s): Dr M Muñoz-Rojas (The University of Western Australia), Dr E Veneklaas (The University of Western Australia)

Restoration of degraded land following mining is challenged by factors including the limited availability of natural



topsoil and low soil fertility. This project aims to assess the effectiveness of current practices in rehabilitation in the Pilbara including the use of soil amendments to improve soil function and seedling recruitment.

Over the past year, a 21-month study was completed examining the benefits of the amendments gypsum and urea added to mine site restoration soils seeded with different mixes of plant species. The amendments had a strong initial effect on soil quality, increasing nitrogen, soil electrical conductivity and nitrogen-mineralisation. Nitrogen levels returned to pre-amendment levels after the first year, and amendments had limited effects on plant growth. However, plant survival was higher in the amended soils for plots seeded with the most diverse plant community, which in turn increased soil microbial activity.



### **Design and testing of novel seed processing equipment and methods to improve seed-based restoration**

STP 2019-014

Scientist(s): D Merritt, T Erickson

Student: E Ling (MSc)

Academic(s): Dr A Guzzomi (The University of Western Australia)

Irregular surface features on native seeds hinder the application of seed coatings and the flow of seeds through seeding machinery. Flash flaming technology removes these appendages from seeds, reduces their volume and enhances their flowability, without impacting on viability. This project aims to apply flaming to diverse species and design and construct new large-scale flash flaming machinery and other post-harvest seed processing equipment.

Three commercial scale, 900-mm diameter seed flamer machines have now been constructed and seed flaming protocols continue to be developed for an increasing diversity of species. Seed flaming has been tested on over 20 species including those of Amaranthaceae, Asteraceae, Chenopodiaceae, and Poaceae. An additional focus of the past year has been to design and construct a compact drying machine for the coating and pelleting of flamed seeds to allow for larger-scale production and testing of these seed enhancements for future field trials.



### **Native seeding mechanisation to facilitate efficient large-scale restoration of degraded lands**

STP 2019-013

Scientist(s): D Merritt, T Erickson

Student: M Masarei (PhD)

Academic(s): Dr A Guzzomi (The University of Western Australia)

Sowing seeds for restoration using direct seeding machinery is challenging as seeds of many native species have complex morphological features that impede their flow through the machinery. This project aims to design, construct, and test new seeding machinery compatible with seeds of diverse native species. Increasing the precision of sowing depth across sloped and rocky landforms common to mine sites is a primary objective.

Two field trials, both of 30 hectares in size, were conducted at mine sites in the Pilbara during the summer of 2020 to test variants of machinery designs across different soil and landform types. The trials included the use of enhanced seeds (flamed, coated and primed seeds). The modified machinery appears effective at placing seeds at depths conducive to emergence. Early monitoring indicates up to a fourfold increase in emergence using these techniques. Monitoring will continue over the coming winter to evaluate seedling survival.



## Assessing ecological resilience of post-mining restoration: testing fire recovery across a restoration chronosequence

STP 2019-060

Scientist(s): B Miller  
 Student: E Cowan (PhD)  
 Academic(s): Dr J Fontaine (Murdoch University), Dr R Standish (Murdoch University)

Ecosystem resilience is the ability of an ecosystem to return to its former state following a disturbance and is a key factor in evaluating the success of ecological restoration efforts, but is unknown for many restored communities. This project investigates the resilience of *Banksia* woodlands after sand mining to fire, specifically seeking to determine an age when restoration is resilient to fire. Investigations will include; functional diversity, resprouting capacity, and soil seedbank dynamics across a chronosequence of ages between three and 27 years since restoration. Small scale burns will also be conducted in this fire adapted ecosystem.

In this year, the project has focussed on establishing sites for experiments and early stages of pre-fire data collection, and implementing smoke tent treatments to assess soil seedbank dynamics in relation to restoration age. A review of restoration resilience studies was submitted for publication.



## Shifting soil fungal communities in response to fire and weed management in urban *Banksia* woodlands

STP 2019-052

Scientist(s): B Miller, K Ruthrof  
 Student: A Brace (PhD)  
 Academic(s): Dr A Hopkins (Edith Cowan University), Dr J Fontaine (Murdoch University)

Issues arising from habitat fragmentation are exacerbated by a warming and drying climate, land use changes and invasive species. To maintain biodiversity, various management methods are employed, such as prescribing burning or herbicide application. Many of these strategies are macro-organism focused, with less attention paid to microorganisms. Soil fungi play instrumental roles in ecosystem functioning, yet in many ecosystems little is known about how soil fungi respond to prescribed burning and weed control. The Swan Coastal Plain's *Banksia* woodland is one such ecosystem where there is a gap in knowledge. This project will help fill that knowledge gap and better inform management decisions.

A range of field and greenhouse experiments are being undertaken. Soils have been collected from a) sites with different 'time since fire', b) sites immediately post fire, and throughout the year, and c) a weed control/fire management study. Investigation of soil fungal community compositional changes, using molecular tools will be undertaken in relation to the factors at these sites.



## Ecologically tolerable fire regimes for key *Banksia* woodland plant species

STP 2018-089

Scientist(s): B Miller, D Merritt  
 Student: R Miller (PhD)  
 Academic(s): Dr J Fontaine (Murdoch University), Prof J Enright (Murdoch University)

Fire is a dominant disturbance that shapes the structure, composition and function of ecosystems around the world. This process has been occurring in the Australian landscape for millennia and such a long engagement with fire means that plants have developed strategies and adaptations to cope with this disturbance in the

landscape. It is important to note that species are built on a tolerance to certain patterns of fire (the fire regime) rather than simply to fire itself. If fire occurs too frequently, too intensely, or otherwise outside of the limits of a species tolerance, then populations are likely to decline or disappear. This project aims to determine the impact of varying fire regimes on the demographics of key *Banksia* woodland plant species.

Population size structure, flowering, and canopy seed bank surveys were conducted for six shrub and tree species along a fire age chronosequence. These suggest that some species have different demographic behaviour in *Banksia* woodland than elsewhere (e.g. kwongan shrublands), with, for instance, inter-fire recruitment potentially allowing some to persist in the long absence of fire. Juvenile periods ranged from 1.3-4.1 years and varied by fire response, seed bank storage mode, and growth form. Canopy seed banks were not observed to accumulate over time, consistent with observations of weak serotiny in *Banksia* woodlands. A separate field experiment showed how timing of seed planting throughout the year (emulating the timing of fire) influences seedling recruitment, where recruitment is best when seeds are cued for germination immediately prior to winter rainfall. Data collection and analysis has been completed, and writing is close to completion. A review paper has been published, and a paper submitted for publication.



### Fire intensity, seasonal variation and seeds traits may influence seed fates in *Banksia* woodlands

STP 2018-087

Scientist(s): B Miller, D Merritt

Student: R Tangney (PhD)

Academic(s):

In fire-prone ecosystems, recruitment from seeds following fire is prolific and provides a pathway for populations to expand into new niches and persist through fire. For many species, recruitment from seed is their only means of population recovery following fire events, so seed survival through fire is vital in order to maximise post-fire recruitment. This project aimed to measure spatially diverse temperatures within soil during fire, examine lethal tolerances of seeds to elevated temperatures associated with fire, establish interactions between lethal tolerances and emergence behaviour and predict weather conditions that may decrease seeds ability to survive fire events.

Three papers have been published directly from this project: (1) a new method was developed for measuring soil temperatures during fire using distributed temperature sensing within optic fibre to sample spatial and temporal patterns with a much greater extent than previously possible; (2) a negative relationship was identified between seed moisture and lethal temperature thresholds of seeds; and (3) relationships between fuel loads and temperature penetration into soils were analysed, as well as the depth from which seeds are able to emerge from soils and their lethal temperature thresholds. In particular, this study has discerned that even though larger seeds can emerge from deeper within the soil, they are not necessarily better at surviving elevated soil temperatures.



### The social structure of a reintroduced population of boodies (*Bettongia lesueur*) at Matuwa, Western Australia

STP 2019-056

Scientist(s): K Ottewell, C Lohr, M Byrne

Student: A Cooke (MSc)

Academic(s): Dr J Kennington (The University of Western Australia)

Boodies (*Bettongia lesueur*) utilise complex warren systems for shelter and protection from predators, with multiple individuals (sometimes up to 50) sharing the same warren. This project aimed to identify the demographic, social and genetic characteristics of group-living boodies at Matuwa, an arid zone reintroduction site.

All laboratory and statistical analyses have been completed. Microsatellite analyses suggested that social

structuring is present in the boodie population at Matuwa, with female boodies showing significantly higher relatedness within warrens than between. Males showed no pattern in relatedness within and between warrens suggesting male-biased dispersal. With the exception of one warren, all warrens had multiple mitochondrial haplotypes indicating multiple females contributing to reproduction. Future translocations of boodies may benefit by retaining familial social groups.



### Individually identifying feral cats to investigate population densities and trends in the Pilbara, Western Australia

STP 2020-019

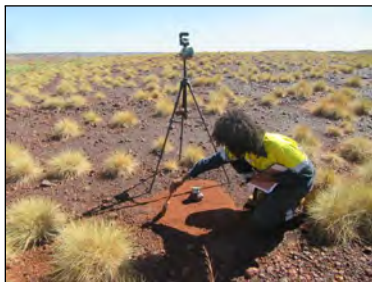
Scientist(s): R Palmer

Student: A Johnson (MSc)

Academic(s): H Moore, P Withers (The University of Western Australia)

Camera traps are useful for detecting feral cats, but questions remain over the use of these devices for large-scale and long-term monitoring. This project is looking to individually identify feral cats from images obtained during a four-year systematic camera trap monitoring program in the Pilbara. If feral cats are recognisable from their coat patterns, this would allow for spatially explicit capture-recapture methods to be used to estimate cat densities, permitting improved assessment of control programs.

Over the study, 3,568 camera trap images of feral cats were captured representing 299 cat visits. At least 142 individuals have been identified from their markings; 88 at the unbaited site and 54 at the baited site. More individuals were recaptured in the unbaited treatment (36 cf. 17 cats in baited cell). Few cats were detected both before and after a baiting episode, although some adults survived at least one baiting operation.



### Testing of methods to exclude northern quolls (*Dasyurus hallucatus*) and other non-target species from soft-catch leg-hold traps set for feral cats in the Pilbara.

STP 2019-063

Scientist(s): R Palmer

Student: H Abdi (BSc Honours)

Academic(s): Dr S Tomlinson (Curtin University), Dr B Bateman (Curtin University)

Soft-catch leg-hold traps are used by departmental staff to capture feral cats for research or control purposes. Leg-hold trap sets occasionally capture unintended species that also show interest in the lures used to attract feral cats. To ensure northern quolls (*Dasyurus hallucatus*), an endangered native carnivore, were not harmed during feral cat leg-hold trapping programs in the Pilbara, experiments were undertaken to identify ways to capture larger-sized feral cats whilst excluding the smaller-sized quolls.

Modified leg-hold traps (one jaw removed) were trialled in northern quoll habitat to test traps set at differing trigger pressures visited by adult quolls. Some traps requiring 4.4 N of pressure to trigger were set-off by quolls, but none requiring 8.8 N force were triggered by them (~25 percent the mass of an adult feral cat). All leg-hold traps were tensioned to this setting for the subsequent feral cat trapping programs and no quolls were captured.



## Taxonomy and evolutionary history of *Australocypris* giant ostracods from Australian salt lakes

STP 2020-012

Scientist(s): A Pinder  
 Student: M Rahman (PhD)  
 Academic(s): Dr J Chaplin (Murdoch University)

Salt lakes are a distinctive feature of Western Australian inland areas. Several invertebrate groups appear to be far more diverse in Western Australia than anywhere else in Australia and even globally, probably reflecting the long history of aridification and the now disjunct occurrence of this type of wetland in the State. Salt lakes and their biota are threatened by altered hydrological processes and changes in water quality associated with land clearing (especially in the Wheatbelt) and increasingly, by mining on or near the lake bed. The first goal of the project is to use mitochondrial DNA data and, if necessary, nuclear DNA data, to assess the validity of the morpho-taxonomy of genus *Australocypris*, which is one of the most diverse genera in Australian salt lakes. The second goal is to use molecular data to test alternative hypotheses about species radiations in *Australocypris*, whose evolutionary history is largely unknown. The final goal is to develop a protocol for hatching and raising adult ostracods from resting eggs in mud samples collected from dry lakes, as a substitute for collecting active ostracods.

A review of the biology of non-marine giant ostracods (Crustacea, Cyprididae, Mytilocypridini) is being prepared for publication. Twenty-eight sample populations of seven species of *Australocypris* have so far been collected from the salt lakes of Western Australia and identified based on the current morpho-taxonomy. Molecular analyses and hatching experiment will commence shortly.



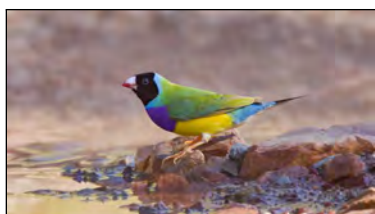
## Taxonomy, ecology and evolutionary history of the salt lake gastropod *Coxiella*

STP 2020-010

Scientist(s): A Pinder  
 Student: A Lawrie (PhD)  
 Academic(s): Dr J Chaplin (Murdoch University)

Salt lakes are an iconic feature of Western Australian semi-arid and arid landscapes, with a flora and fauna that has adapted and diversified within these extreme environments. Several groups appear to be far more diverse in Western Australia than anywhere else in Australia and even globally. Salt lakes and their biota are threatened by altered hydrological processes and changes in water quality associated with land clearing (especially in the Wheatbelt) and increasingly, by mining on or near the lake bed. One of the most intriguing invertebrate groups is the snail genus *Coxiella*, which tolerates both periodic drying and high salinities and is the only mollusc occurring in temporarily filled salt lakes. This project focusses on the taxonomy, ecology and evolutionary history of this genus.

A literature review is in preparation that will collate information on the biology of halophilic and halobiontic crustaceans and gastropods of Australian salt lakes. Most of the samples required for the taxonomic component of the project have been collected, including fresh specimens from salt lakes throughout south-west Western Australia and several samples from museums. Sampling for species that occur outside of Western Australia is also being undertaken. Combining these samples will permit a thorough assessment of the current taxonomic framework and is likely to identify new species.



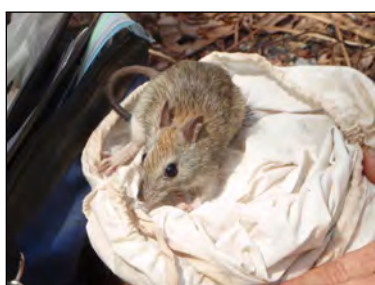
## Influence of fire history and seed distribution on the movements of granivorous finches in the East Kimberley

STP 2019-057

Scientist(s): I Radford  
 Student: S Collett (PhD)  
 Academic(s): Dr H Campbell (Charles Darwin University)

Populations of the granivorous Gouldian finch (*Erythrura gouldiae*) have not recovered from historical population declines prior to the 1980's. It is hypothesised that this lack of recovery is due to a decline in grass seed diversity in response to higher frequency and intensity fires across the landscape, which is forcing Gouldian finches to move longer distances to meet their dietary requirements in a more homogeneous landscape. The project aims to estimate the activity range, habitat use and dispersal for threatened Gouldian finches, and compare this with the more common masked and long tailed finches, to look at reasons for rarity in Gouldians and also to design management options to improve Gouldian finch status. This presents technical challenges due to the small size and high mobility of study animals using automated radio telemetry.

This project is in the analysis phase and field work is complete. Novel telemetry techniques delivered over 20 million fixes on 166 individual finches (approximately 50K detections/individual). Redetection rates were 92 percent compared to conventional banding recapture rates of only 1.7 percent. Core areas of finch activity are being analysed, and this information will be used to model key explanatory variables for finch movements across savanna landscapes. Spatial distribution of different grass species and their seeds, fire mosaics and nesting hollow density will be used in models to determine what drives threatened finch movements. Isotopic analysis of finch blood samples has revealed significant niche differentiation between the three finch species and also seasonal variation in diet. Gouldian finches had lower dietary nitrogen than either long tailed or masked finches, supporting the hypothesis that they are specialised granivores, whereas the other species supplement their diet with invertebrates. Write-up and analysis is underway.



## Is there a housing crisis in tropical savannas? Changing fire regimes, hollows and declining arboreal mammals

STP 2017-017

Scientist(s): I Radford  
 Student: C E Penton (PhD)  
 Academic(s): Dr LA Woolley (Charles Darwin University), Dr B Murphy (Charles Darwin University)

There has been a significant amount of research conducted in northern Australia regarding fire regimes and their effect on savanna systems. However, the fire ecology of tree hollows has not been studied in northern Australia. It has been suggested that the drivers of tree hollow development and retention will be different to that known from studies in southern Australia, as savanna systems experience different fire regimes and are subjected to additional processes such as cyclone events and termite activity. Tree hollows are an important ecological resource for around 40 percent of vertebrates in the Top End including mammals, reptiles and birds. Developing optimal strategies for managing fire for arboreal mammals and thresholds of hollow abundance mediated by fire frequency and intensity will be a major advance in our understanding of Australian forest ecology and conservation in northern Australia.

This research into hollow use by multiple arboreal groups, including both competitors and potential predators, and also the action of termites in blocking off tree hollows, has highlighted the relative shortage of this resource for threatened mammals. Statistical modelling is currently underway to determine the effects of fire mosaics on tree hollow availability. This study has already shown that large hollows, which are preferred by threatened arboreal mammals, are more common in savannas where late dry season wildfires and cyclones are less frequent. Although considerable overlap in use of hollows exists between arboreal mammals, some niche differentiation occurs. The smallest of the species, *Conilurus penicillatus*, preferentially uses hollows closer to the ground and in dead trees and logs, which may increase the impacts of terrestrial threat to this species

including fires and predation by feral cats.



### Regeneration of canopy species following drought-induced die-off in the Northern Jarrah Forest

STP 2020-015

Scientist(s): K Ruthrof  
 Student: T Rasmussen (BSc Honours)  
 Academic(s): Dr J Fontaine (Murdoch University), Dr L Walden (Murdoch University)

Forests are an essential asset for the provision and regulation of ecosystem services and culture and heritage. How trees regenerate and adapt to a changing environment is a concern given the expected increase in the frequency, intensity and duration of drought and heatwave events, coupled with wildfires. The Northern Jarrah Forest is one forest ecosystem that has been affected by disturbance events, such as the 2010/2011 drought and heatwave event, and the 2016 Waroona/Yarloop bushfire, which covered an estimated 360 km<sup>2</sup>.

This project aims to determine how these disturbances, and prescribed burning, influence tree regeneration, by asking the following questions: a) how does tree regeneration vary with fire severity and drought? b) how do the growth stages of tree regeneration vary by drought, fire type and history? c) how does seedling density change over time? and d) how do understorey and overstorey regulate recruitment? All field work has been completed and analysis is underway.



### Effects of drought and wildfire on ecophysiological functioning in the Northern Jarrah Forest

STP 2020-014

Scientist(s): K Ruthrof, W Lewandrowski  
 Student: N Anderson (BSc Honours)  
 Academic(s): Dr L Walden (Murdoch University), Dr J Fontaine (Murdoch University)

The south-west of Western Australia is predicted to become drier and hotter in the future. This changing climate is expected to increase the extent and severity of wildfire. Knowing how forest ecosystems will respond to both drought and fire is critical for informed forest management, particularly for vulnerable sites. The Northern Jarrah Forest (NJF) experienced droughts in 2010 and 2015, and a wildfire in 2016 (Yarloop). This project uses established monitoring plots from inside, and adjacent to, the Yarloop fire scar to measure the ecophysiological response of the canopy species jarrah (*Eucalyptus marginata*) to drought and fire.

Re-sprouting stems at drought and fire-impacted sites were measured in summer and winter for pre-dawn leaf water potential, stomatal conductance, chlorophyll fluorescence, specific leaf area, and live foliar moisture. Combined, these measurements provide a better understanding of how the keystone species of the NJF is recovering and functioning after a series of disturbances.



### Evolution of C<sub>4</sub> photosynthesis in the genus *Tecticornia* at the anatomical and molecular levels

STP 2017-044

Scientist(s): K Shepherd, T Macfarlane  
 Student: N Dakin (PhD)  
 Academic(s): Dr M Ludwig (The University of Western Australia), Prof G Kadereit (Mainz University, Germany)

This study aims to study the evolution of C<sub>4</sub> photosynthesis in the genus *Tecticornia* (Chenopodiaceae) at the molecular and anatomical levels. The genus includes two species identified as using the C<sub>4</sub> photosynthetic

pathway, and 39 species currently categorised as C<sub>3</sub> plants.

The project has contributed to the resolution of relationships between species of *Tecticornia* using molecular phylogenetic data and identified C<sub>3</sub> species most closely related to C<sub>4</sub> species. However, further molecular and anatomical analyses identified *Tecticornia auriculata*, a species that is not particularly closely related to the C<sub>4</sub> clade, as being a C<sub>3</sub>-C<sub>4</sub> intermediate. *T. auriculata* has C<sub>4</sub>-like anatomical features, an increased investment of organelles in lower mesophyll cells, and lower levels of photorespiration compared to other C<sub>3</sub> species. By looking at C<sub>3</sub>, intermediate, and C<sub>4</sub> *Tecticornia* species, the steps in the evolution of C<sub>4</sub> photosynthesis in this genus seem to deviate from the most widely accepted model of C<sub>4</sub> evolution. *Tecticornia* species have ultrastructural differences in upper and lower mesophyll cells, rather than mesophyll and bundle sheath cells. Lower cells are not enlarged, and changes in GDC-P localisation do not seem to play a major role. The steps towards C<sub>4</sub> photosynthesis in *Tecticornia* follow the model in other ways, with an increased investment in organelles in lower cells being an important step. The unusual anatomy of succulent articles and the halophytic habit of *Tecticornia* may explain this unusual route towards C<sub>4</sub> photosynthesis.



### Restoring highly degraded *Banksia* woodlands through innovative seed enhancement technology

STP 2018-150

Scientist(s): J Stevens, T Erickson

Student: V Brown (PhD)

Academic(s): Prof R Hobbs (The University of Western Australia), Dr A Ritchie (The University of Western Australia)

Restoration of native plant communities through direct seeding often have low seedling establishment success rates. A significant factor in restoring post pine and degraded agricultural lands back to native vegetation is competition with invasive weed species, and as native seedlings are susceptible to herbicide application, weed control strategies are limited. This project will examine how seed pelleting technologies can be applied to biodiverse *Banksia* woodland species to protect seeds from herbicide application and offer innovative weed control strategies for restoration in high weed load environments.

A large field trial was established within a post-pine and post-mine site. Approximately 39,000 *Jacksonia furcellata* seeds were planted out across five different management treatments (i.e. herbicide, rip, rip then herbicide, herbicide then rip or control) to test the efficacy of different seed enhancement technologies to protect against a post-emergent herbicide (fusilade). These seed enhancement technologies include extruded pellets or seed coatings with either activated carbon or biochar (both ingredients known to adsorb herbicides) and a control where seeds were left untreated (no seed enhancement technology). Peak emergence data showed that most seed enhancement technologies did not impede emergence of *J. furcellata*. When looking at seed enhancement technology as an overall treatment, one type of extruded pellet had 73 percent mean emergence, which was higher than the control (59 percent). The site (post-pine or post-mine) and management treatment (rip, herbicide or control) did not affect mean emergence. In comparison, *J. furcellata* mean survival (251 days after planting) was impacted by site as a treatment. The post-pine site had an overall mean survival of 8 percent, compared to 35 percent at the post-mine site.



### The influence of drought on plant morphology, physiology and establishment in the post iron ore mining environments of semi-arid Western Australia

STP 2018-147

Scientist(s): J Stevens

Student: S Sullivan (PhD)

Academic(s): A/Prof P Poot (The University of Western Australia), Dr E Veneklaas (The University of Western Australia)

Mining companies have a legal responsibility to return native biota to post-mining environments; however, ecological restoration is challenging, especially in water limited environments. The chemical and physical



properties of substrates do not always explain high seedling mortality therefore other factors such as drought should be explored. This research project aims to improve restoration outcomes by obtaining a greater understanding of the influence of soil water availability and phenotypic plasticity on juvenile plant morphology, physiology and survival in the post iron ore mining environments of semi-arid Western Australia.

Field trials were undertaken in which greenstock and seeds of six endemic species were introduced onto a waste rock dump and exposed to experimental watering regimes. Seedling emergence, survival, growth and physiology was monitored over a period of 18 months to examine the effect of rainfall frequency and intensity on seedling performance. Hydrothermal germination thresholds for seeds of the six study species were explored further in a series of lab trials. A glasshouse trial investigating how preconditioning seedlings to water stress influences tolerance to subsequent drought was also completed. Data analysis and report preparation is underway for the field, lab and glasshouse trials.



## Near-surface remote sensing of plant condition in mine site restoration environments

STP 2018-146

Scientist(s): J Stevens

Student: J Ruscalleda Alvarez (PhD)

Academic(s): Dr J Yong (The University of Western Australia), Dr E Veneklaas (The University of Western Australia)

Plant physiological condition is a key indicator in the early stages of restoration progress assessment. Current methods to determine condition are difficult to undertake over large areas and are time consuming. This research project aims to determine if near-surface remote sensing measurements (particularly hyperspectral sensing and thermography) can reliably quantify plant drought stress condition in a biodiverse plant community. Quantitative criteria will be proposed to evaluate restoration success by defining a fast, accurate and easy to perform methodology, and potentially establishing the foundation for scaling up to more remote imaging platforms that allow monitoring of larger areas in shorter periods of time.

Data analysis from a controlled drought glasshouse experiment is showing that optimised spectral indices in the short wave infra-red spectral region can accurately predict leaf water potential and relative water content in different plant functional types typical to the *Banksia* woodland vegetation. This is true both at the leaf scale using an internal light source, as well as at plant canopy level using a non-reflective background and natural illumination conditions. Thermography data analysis, although at an early stage, is showing a general solid relationship between leaf temperature and stomatal conductance, although it is variable across species. In a field experiment carried out in a restored *Banksia* woodland, ecophysiological performance of young plants (3 to 4 years old) of five plant species of different functional types was monitored throughout a natural seasonal cycle, in parallel with hyperspectral reflectance and thermography measures. Water relations and drought stress adaptations differed between species, outlining a clear gradient from drought-avoider species to drought-tolerant species. Preliminary analysis of hyperspectral data at the leaf level shows that full and/or partial spectrum analysis through Partial Least Square Regression as well as optimised spectral indices can accurately predict leaf water potential, relative water content and especially leaf water content levels, although to a lesser extent than in our glasshouse experiment. Preliminary results also show prediction models to be not reliable when using canopy level reflectance data, where soil and litter background reflectance interfere with plant tissue reflectance.



## Soil-microbial-plant signals and effects on plant eco-physiological performance for mine site restoration

STP 2018-145

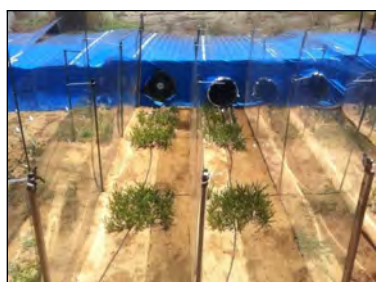
Scientist(s): J Stevens

Student: W Wong (PhD)

Academic(s): A/Prof R Trengove (Murdoch University), Dr J Yong (The University of Western Australia), Dr E Veneklaas (The University of Western Australia)

The importance of soil biological properties such as microbial composition and the benefits conferred to soils and plants are often undervalued in mine site restoration. Microorganisms have been widely reported to be beneficial for agricultural crops (e.g. growth stimulation, increased nutrient uptake, plant tolerance against abiotic stress such as drought) through inducement by microbial signals, such as phytohormones and enzymes. Some of these beneficial microorganisms are also present in natural soil systems; however, their role in facilitating seedling establishment is yet to be identified. This project aims to investigate if microorganisms known to benefit agricultural species can be applied to the Western Australian natural systems via inoculations. The project also aims to elucidate the mechanisms involved in the positive effects of microorganisms on the plants and explore how these findings can be integrated to improve mine site restoration strategies.

Initial findings indicated that plant species had different responses towards microbial inoculation treatments, exhibited via physical and/or physiological characteristics. Further analysis is being undertaken to understand the intricate interactions between plants and microorganisms by assessing the link between improved plant physiological performance with foliar nutrient and stable isotope content and changes in xylem sap phytohormone profiles in microbial inoculated plants.



### Implications for wind management in restoration ecology, linking ecosystem aerodynamics to physiological drivers in arid and semi-arid systems

STP 2018-143

Scientist(s): J Stevens

Student: E Arora (PhD)

Academic(s): Dr A Guzzomi (The University of Western Australia), Dr S Tomlinson (Curtin University), Prof K Dixon (Curtin University)

Plant mortality in restoration programs leads to reduced outcomes for biodiversity and is costly for practitioners. Understanding the drivers of mortality, in particular factors influencing soil water availability are critical. Wind dynamics play a significant role in drying soils and creating atmospheric deficits whereby plants lose water. In altered systems such as restoration environments, the wind dynamics may be different compared to reference communities and may impact seedling establishment. This project aims to capture reference wind dynamics of many Western Australian ecosystems including the *Banksia* woodland ecosystem, and compare restoration sites to the reference state. Understanding the critical thresholds for wind dynamics and the impacts on plant physiological performance will be assessed for *Banksia* species.

The investigation so far has identified canopy flow wind regimes across several native Australian vegetation communities and mapped the decay and regeneration of aerodynamic wind patterns across a restoration chrono-sequence. A seedling, historically adapted to emerge in a less windy environment, is likely to experience high levels of stress when seeded on restoration sites with extreme early-stage wind regimes. Physiological trials indicated significant impact of increased wind velocity on seedling mortality and biomass, and explored mechanistic drivers connecting localised aerodynamic flow and vegetation establishment. A more comprehensive understanding of wind as a factor in restoration will allow for anthropogenic manipulation of wind and microclimates onsite to provide necessary shelter for seedlings until sufficient canopy features have established, and facilitate a more rapid and efficient reintroduction of plants, pollinators, and functioning ecosystem services.



### How do species interactions drive community assembly of *Banksia* woodlands?

STP 2018-142

Scientist(s): J Stevens, B Miller

Student: L Svejcar (PhD)

Academic(s): Dr J Fontaine (Murdoch University), Dr R Standish (The University of Western Australia)

Over time, the diversity of plant species present in restoration sites decreases. In particular, many seedlings

die after their second summer of growth, which is posited to be the result of plants competing for limited soil water and nutrient resources. However, plant-plant interactions have not been extensively studied in this ecosystem. This research project is investigating: (1) what do spatial patterns among species reveal about the importance of competition and facilitation in early and mid-successional stages of community development following restoration?; (2) do varying densities of a native annual grass (*Austrostipa compressa*) facilitate growth of seedlings from topsoil transfer?; and (3) do clustered or dispersed seeding strategies increase or decrease seedling survival?

Spatial mapping of individual perennial plants was conducted in five restoration areas at 1, 2, 3, 7 and 11 years old. Three field trials were established: (1) a two year study to determine whether the spatial interactions of seedlings differs based on their ability to fix nitrogen; (2) a two year study testing the impact of six densities of *A. compressa* (0, 20, 165, 310, 455 and 600 *A. compressa* m<sup>-2</sup>) on seedling diversity and establishment; and (3) a one year study testing varying spatial arrangements of planted seed. Results demonstrated that plant-plant interactions play a critical role in the survival of some species and spatial arrangement effects restoration outcomes. In particular, single species patch plantings may be beneficial for the survival of some species that do not persist using current restoration methodologies, such as *Allocasuarina fraseriana*.



### Dolphin health - toxicogenomics and pathology investigations

STP 2020-069

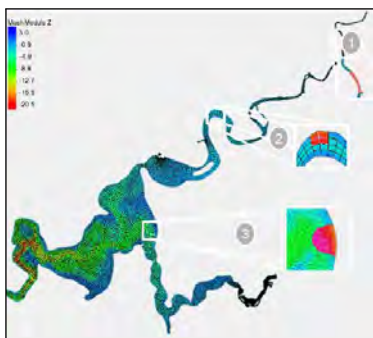
Scientist(s): K Trayler

Student: N Stephens (PhD)

Academic(s): Dr K Warren (Murdoch University), Dr C Holyoake (Murdoch University), Dr P Duignan (University of Calgary)

In 2009, following the deaths of six dolphins in one year in the Swan Canning Riverpark, a collaborative project with Murdoch University was established for ongoing support in post-mortem investigations of individual strandings and unusual mortality events. That work was instrumental in understanding the underlying factors in the dolphin mortality event of 2009 and effort to understand dolphin health continues to be supported through the department and Murdoch University. Pathology investigations are linked to this research project examining toxicogenomics and contaminant exposure in live dolphins.

The project will evaluate if there is any evidence of sub-lethal adverse effects on the immune, endocrine and nervous systems of dolphins that use the Riverpark. These dolphins are being compared with dolphins in Shark Bay, as a 'control population' in order to evaluate the potential threats faced by and overall health of dolphins in the Riverpark community. Necropsy and pathology testing of deceased cetaceans in 2019 indicate the return of cetacean morbillivirus to the Swan Canning Riverpark. More widely, the virus has affected dolphins between Bunbury and Shark Bay and impacting both Indo-pacific bottlenose dolphins and striped dolphins.



### Identification of controls on the metabolism of the Swan-Canning Estuary using numerical modelling and high-frequency data

STP 2018-093

Scientist(s): K Trayler

Student: A Saeed (PhD)

Academic(s): A/Prof M Hipsey (The University of Western Australia), Prof C Oldham (The University of Western Australia)

The Swan Canning Estuarine Response Model (SCERM) is an important tool for management of the waterway. The model has been shown to capture seasonal and spatial variability in some physico-chemical parameters, but could be improved through targeted research. This project is working to improve understanding of the estuarine metabolism of the waterway through high frequency monitoring. New understandings will be applied to improving model dynamics.

High frequency data has been collected at three nearshore locations (Guildford, Maylands and Como) for diurnal oxygenation analysis and time series plotting. A monitoring buoy was established in the deeper waters off Heathcote and now provides real-time data on chlorophyll-a, oxygen and temperature dynamics. These nearshore and offshore data are together being used to validate oxygen dynamics in the Swan Canning Estuarine Response Model.



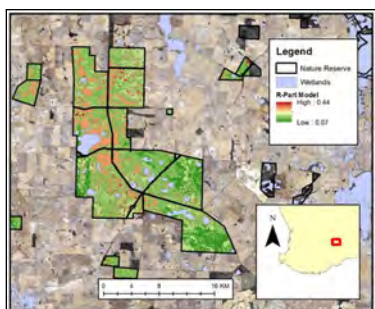
### Species distribution modelling of feral cats in the Pilbara, Western Australia

STP 2020-036

Scientist(s): R Van Dongen, R Palmer  
 Student: S Williamson (MSc)  
 Academic(s): Dr T Robinson (Curtin University)

Managing the impacts of feral cats on threatened fauna in the Pilbara is challenging, as cats are both difficult to control and to monitor at the landscape scale. The purpose of this study is to use spatial data, such as Landsat imagery and digital elevation models, together with ground-based data, from camera traps and tracking collars, to create a species distribution model for feral cats in the Pilbara bioregion.

A literature review has been completed and a research design has been formulated that identified cat location data including camera trap data and tracking collar data as training/validation inputs for building a model. Spatial data sets to be used as model inputs include Landsat imagery, digital elevation model, fire history, vegetation mapping and streamline data. Classification models to be investigated were identified, including random forest and maximum entropy.



### Senescence mapping in the southern Wheatbelt

STP 2020-035

Scientist(s): R Van Dongen  
 Student: T Baskerville (3rd year)  
 Academic(s): Dr T Robinson (Curtin University)

Changes in historical fire regimes have led to reduced fire frequency in some ecosystems. This had resulted in significant areas of senescence particularly in Wheatbelt reserves. The aim of this study was to identify areas of senescent vegetation in these reserves. To do this, the relationship between tree mortality counts from field transects at areas of senescence (n = 71) and satellite imagery data sets were analysed.

Several satellite imagery derived indices and models were tested using individual and multi-temporal imagery. The best performing model to predict mortality used multi-temporal satellite images and a recursive partitioning model ( $r^2 = 0.67$ ). This model was then applied to four reserves in the southern Wheatbelt and Wongan Hills in the north. Maps of potential senescence were also produced and delivered to regional staff.



### Home range, site fidelity and social structure of snubfin dolphins in Roebuck Bay, Western Australia

STP 2020-042

Scientist(s): K Waples, H Raudino  
 Student: A D'Cruz (BSc Honours)  
 Academic(s): Dr C Salgado Kent (Edith Cowan University)

Yawuru Nagulan/Roebuck Bay Marine Park (YNRBMP) is known as a 'hotspot' for snubfin dolphins and this species is recognised as a key ecological value of the marine park. As anthropogenic pressures increase in

the bay from growing recreational use and increasing tourism and industrial activity, there is a need to better understand snubfin dolphin population dynamics in the reserve. This study will contribute to understanding how snubfin dolphins use Roebuck Bay at an individual and population level and provide valuable information to managers that will assist the long-term conservation of the species. This project will analyse data from previous studies to provide new information on the population's ecology and biology, specifically in relation to home range, social structure and site fidelity.

While the project initially planned to collect data from tour operator vessels and focus on the overlap between population dynamics and tourism, this could not occur due to restrictions associated with managing COVID-19. The project was modified to focus on analysing existing data and using that information to explore home range patterns and social structure. Data processing and analysis of dolphin photo identification images in the DolFIN database has now commenced.



### Survey methods and population estimates of the chuditch across its range

STP 2020-048

Scientist(s): A Wayne  
 Student: M Taylor (PhD)  
 Academic(s): Dr K Bryant (Murdoch University), Dr N Armstrong (Murdoch University)

Robust population estimates are fundamental to species conservation and management. This study aims to assess and improve the accuracy and reliability of survey methods used for the threatened chuditch (*Dasyurus geoffroyi*).

Existing DBCA data will be used to investigate cage and camera trapping methods to identify possible improvements. Parameters for assessment include increasing detection probabilities, individual identification from camera images, and spatially explicit capture-recapture density estimates. Design elements expected for testing include spatial arrangement of traps, timing of surveys, bait/lure types, and camera trap model and set-up. Trials will be conducted at numerous populations in south-western Australia to provide representation across the species range and habitat types. A literature review on survey and monitoring methods and the biology and conservation of the chuditch is being undertaken.



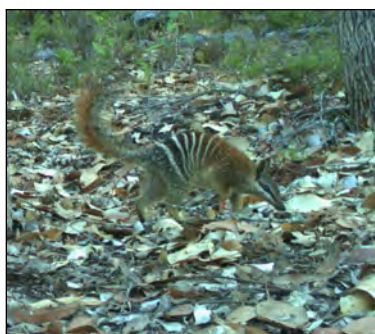
### Modelling species interactions and other environmental factors in the Upper Warren

STP 2019-051

Scientist(s): A Wayne  
 Student: W Geary (PhD)  
 Academic(s): A/Prof E Ritchie (Deakin University), A/Prof D Nimmo (Charles Sturt University), Dr T Doherty (Deakin University), Dr A Tulloch (University of Sydney)

This project aims to identify the major correlates of population changes in four critical weight range (CWR) mammals (woylie, chuditch, koomal, quenda) in the Upper Warren Region of Western Australia, including fire history, logging history, climate and weather variation and predator management. This will be done by modelling trapping data from the region from 2000-2019 across 12 transects against a range of spatially explicit variables. Some analysis will also be conducted on predator sand plot monitoring data collected between 2006 and 2012 in the Upper Warren Region, relating this to predator management intensity and other correlates.

Dynamic occupancy models of red fox and feral cats across the Upper Warren have been built using the sand plot monitoring data in relation to predator baiting intensity and rainfall. Mark-recapture modelling has also been undertaken on woylie, chuditch, koomal and quenda to calculate transect-specific abundance estimates over time across the Upper Warren. Covariates for modelling have also been built that include baiting intensity, fire regime, timber harvesting and primary productivity. Next steps will entail relating these environmental and management variables to these abundance estimates to identify strong correlates of abundance for each species.



## The population and spatial ecology of the numbat in the Upper Warren

STP 2019-050

Scientist(s): A Wayne  
 Student: S Thorn (PhD)  
 Academic(s): A/Prof N Mitchell, Dr R Firman (The University of Western Australia)

The aim of this project is to increase knowledge about the baseline population and spatial ecology of the numbat in the Upper Warren region. This information will assist in informing future management practices for this population.

Based on preliminary spatially explicit capture recapture modelling, a camera trap survey was designed and deployed in two areas in the Upper Warren region. This will assess the reliability of camera traps, in combination with capture recapture modelling, for estimating population parameters. GPS collar data was also collected for six numbats between October-December 2019, and March-May 2020. These data will provide insights into home range estimates, habitat use and fine scale movement patterns. In upcoming work, camera traps will be deployed more widely across the region to obtain population parameter estimates for the Upper Warren population. More GPS collars will be fitted to obtain spatial data from a wider representation of the population.



## Survey methods and ecology of the numbat population at the Upper Warren region

STP 2017-041

Scientist(s): A Wayne  
 Student: A Seidlitz (PhD)  
 Academic(s): Dr M Calver (Murdoch University), Dr K Bryant (Murdoch University), Dr N Armstrong (Murdoch University)

This study aims to improve the understanding of the numbat population in the Upper Warren region, to inform management for the conservation of this endangered species. The objectives are to develop robust survey methods for numbat population monitoring, and to determine anthropogenic and environmental factors influencing the population.

Different camera trap models and set up options were evaluated to improve numbat detection. Swift 3C wide angle camera traps set at 25 cm above ground performed best. Sign surveys detected numbats more efficiently than driven transects and camera trapping. To further explore and improve camera trapping for Upper Warren native species including numbats, a field trial established that Reconyx PC900/HC600 camera traps missed 54 percent of known animal visits while Swift 3C wide-angle camera traps missed only 0.5 percent. A broad scale survey of 78 study sites with varying habitat and management characteristics was undertaken. Numbats appear to be generalists with no clear preference for any key habitat or management type in the Upper Warren region.



## Evidence based management of foxes adjacent to turtle beaches in Western Australia

STP 2016-025

Scientist(s): S Whiting  
 Student: J Stuart (PhD)  
 Academic(s): Dr T Fleming (Murdoch University), Dr P Adams (Murdoch University), Dr B Bateman (Curtin University)

This project is investigating fox biology, distribution, seasonality and behaviour in relation to turtle nest predation. Predation by foxes is a key pressure acting on some turtle rookeries and this study will provide

knowledge to inform the long-term management of foxes and turtles.

A draft manuscript has been prepared that describes the spatial patterns of foxes in relation to a major flatback turtle rookery and the influence of season and access to drinking water. This knowledge will help guide fox control at turtle rookeries in the future.



### The health status of marine turtles in northern and western Australia

STP 2016-022

Scientist(s): S Whiting  
 Student: E Young (PhD)  
 Academic(s): Dr R Vaughan-Higgins (Murdoch University), A/Prof K Warren (Murdoch University), Dr L Yeap (Murdoch University), Dr N Stephens (Murdoch University)

This project is assessing the health and disease status of sea turtles in Western Australia, with a focus on flatback turtles, and is investigating dead and injured turtles stranded along the coast and using pathology to diagnose the causes of death. Blood samples are being obtained from healthy turtles to determine reference ranges for species where gaps exist. Parasite infections and fibropapilloma virus are being specifically investigated. Although focused on flatback turtles, other species will be included as opportunities arise.

Field sampling has been completed. A manuscript was submitted for publication on a novel disease related to a multiple species mortality event (fish kill). A draft manuscript on reference blood ranges for flatback turtles was prepared.



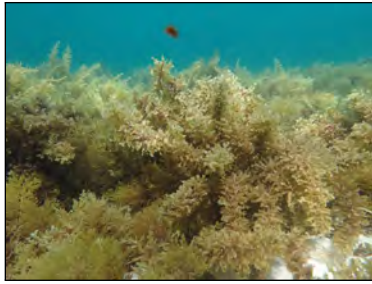
### Habitat quality as a driver of epinepheline serranid productivity and replenishment

STP 2019-038

Scientist(s): S Wilson  
 Student: D Ellis (PhD)  
 Academic(s): Dr C Fulton (Australian National University)

Understanding the habitat requirements of animals and how this influences their distribution is essential for effective management. Ongoing shifts in habitat due to changing climate and acute environmental disturbance emphasise the need to understand how changes in habitat affect associated fauna. Epinephelid serranids are ecologically important predators on tropical reefs that are an attraction for both tourists and fishermen. This project will focus on the habitat requirements of epinepheline serranids at Ningaloo Marine Park, exploring mechanisms that influence their distribution, abundance and productivity. The project will examine fish within two prominent habitat types at Ningaloo, macroalgae and corals, that also represent extremes of the current regime shift paradigm on tropical reefs.

Analysis of surveys within macroalgal and coral reef habitats have found that two of the most common epinephelids, *E. fasciatus* and *E. rivulatus*, are typically found on coral reefs and macroalgal meadows, respectively. More detailed microhabitat surveys within macroalgal meadows revealed that *E. rivulatus* have a close association with hard structures that are >50cm in diameter and holes >10cm diameter. To assess the influence of seasonal fluctuations in macroalgal canopy on *E. rivulatus* distribution, more than 120 fish were tagged on macroalgal patches of different canopy structure in the summer. Follow up surveys will determine if breakdown of macroalgal canopies in the winter affects site fidelity and microhabitat associations of *E. rivulatus*.



## How does environmental disturbance effect macroalgal assemblages at Ningaloo

STP 2019-037

Scientist(s): S Wilson

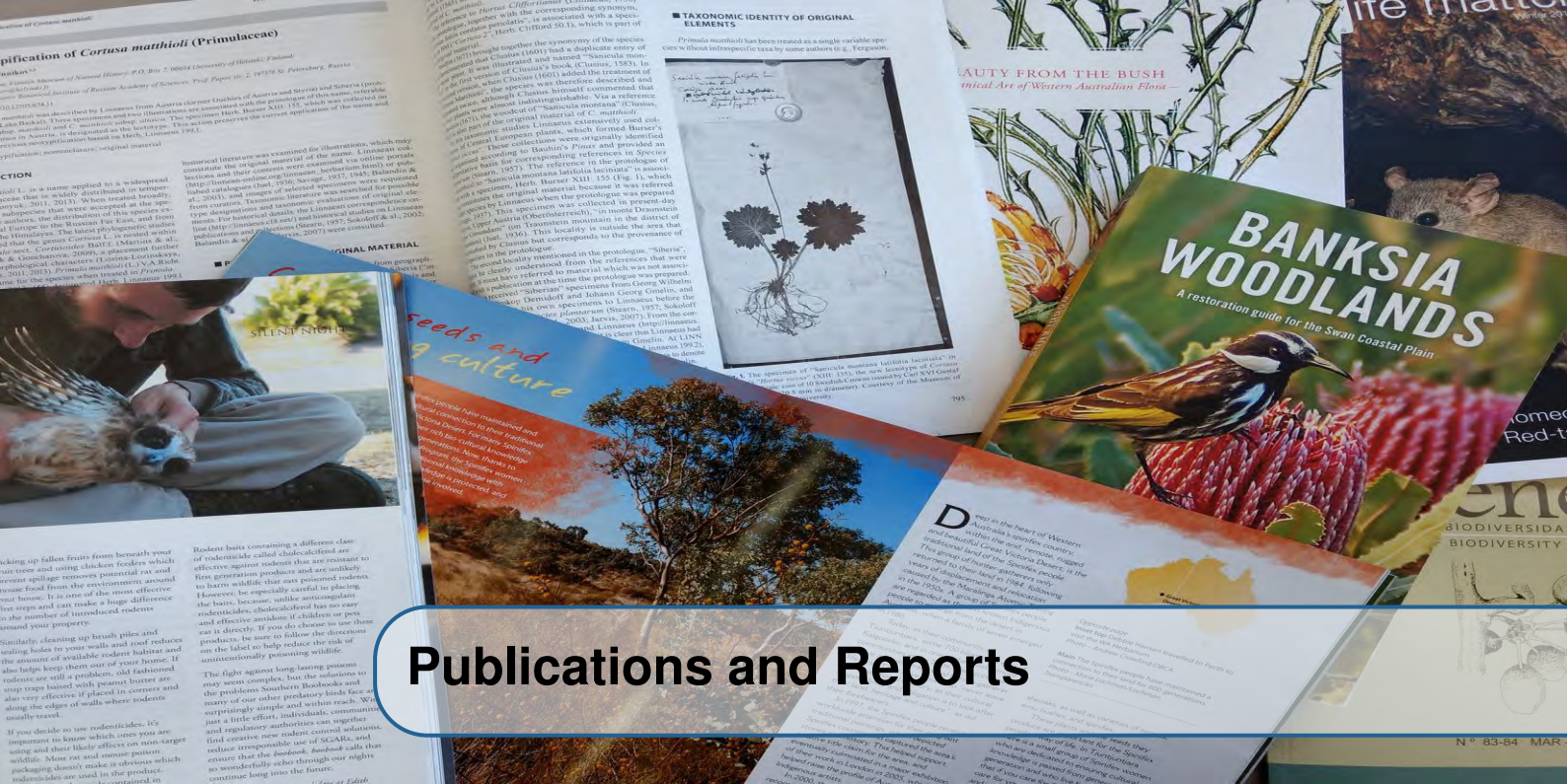
Student: R Harris (MSc)

Academic(s): Dr C Fulton (Australian National University)

Tropical macroalgal meadows can cover extensive areas of the shallow seascape, providing habitat for an abundance of organisms. There is however a paucity of information on processes that drive distribution and structure of tropical macroalgal meadows, particularly how they respond to large-scale natural disturbances. To assess the effects of environmental disturbance on tropical macroalgae, this study will explore temporal and spatial patterns in community composition and physical structure of macroalgal assemblages at Ningaloo Marine Park. The project will analyse macroalgal data collected annually from the Ningaloo lagoon between February 2013 and February 2018, incorporating periods before and after tropical cyclone Olwyn (March 2015) and a major flood event (April 2014).

The study found the cover and height of canopy forming macroalgal fields was greater at sites in the southern part of Ningaloo Reef. Macroalgal diversity was also lower at southern sites compared to those in the north and central regions. Whilst there are temporal differences in macroalgal assemblages, these cannot be definitively linked to floods and cyclones. Further assessment of sites near Coral Bay in the southern region found canopy height and cover was greatest where density of urchins was low and sediment depth was high. Algae from the genera *Sargassopsis*, *Caulerpa*, *Hormophysa*, and *Sirophysalis* were more common at sites with more sediment.





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## Summary of Research Projects

### Animal Science

DBCRA Region	IBRA/IMCRA	NRM Region	Project Title	Page
Pilbara, Goldfields	Pilbara, Gascoyne, Murchison	Rangelands	Barrow Island threatened and priority fauna species translocation program	18
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South Coast, Warren	Jarrah Forest, Esperance Plains, Warren	South West, South Coast	Conservation of south coast threatened birds	21
Goldfields, Swan	Coolgardie, Coastal Plain	Rangelands, Swan	Conservation of the graceful sun-moth	23
Kimberley, Pilbara, Midwest, Goldfields	Tanami, Great Sandy Desert, Pilbara, Carnarvon, Little Sandy Desert, Gibson Desert, Gascoyne, Murchison, Great Victoria Desert	Rangelands	Conservation of the night parrot	5
Pilbara	Pilbara	Rangelands	Decision support system for prioritising and implementing biosecurity on Western Australia's islands	13
Pilbara, Midwest, South Coast	Carnarvon, Gibson Desert, Gascoyne, Murchison	Rangelands, Swan	Development of effective broad-scale aerial baiting strategies for the control of feral cats	25
Midwest	Yalgoo, Shark Bay	Rangelands	Dirk Hartog Island National Park Ecological Restoration Project – fauna reconstruction	8
Pilbara	Pilbara	Rangelands	Ecology and management of the northern quoll in the Pilbara	22
Wheatbelt	Avon Wheatbelt	Avon	Feral cat control and numbat recovery in Dryandra Woodland and other sites	20
Pilbara, Swan	Pilbara, Swan Coastal Plain, Jarrah Forest	Rangelands, Swan	Genetic approaches for evaluating the contribution of the reserve system to fauna conservation	17

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
Kimberley, Pilbara	Northern Kimberley, Central Kimberley, Dampierland, Pilbara	Rangelands	Genetic assessment for conservation of rare and threatened fauna	15
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Kimberley	Victoria Bonaparte, Northern Kimberley, Ord Victoria Plain, Central Kimberley	Rangelands	Impact of cane toads on biodiversity in the Kimberley	24
Pilbara	Pilbara	Rangelands	Improved fauna recovery in the Pilbara – benefitting the endangered northern quoll through broad-scale feral cat baiting	10
All Regions	Gascoyne	All Regions	Improving the use of remote cameras as a survey and monitoring tool	11
Midwest	Geraldton Sandplains	Rangelands	Monitoring of threatened birds on Dirk Hartog Island	11
Goldfields	Gascoyne	Rangelands	Rangelands restoration: reintroduction of native mammals to Matuwa (Lorna Glen)	19
South West	Jarrah Forest	South West, South Coast	South West Threatened Fauna Recovery Project: Southern Jarrah Forest	7
Kimberley	Northern Kimberley, Central Kimberley	Rangelands	Structured decision making for optimal feral herbivore management for biodiversity conservation in the Kimberley	3
All Regions	All IBRA Regions, All IM-CRA Regions	All Regions	Structured decision making for translocation	4
South Coast	Warren	South Coast	Understanding and reducing python predation of the endangered Gilbert's potoroo	6

## Plant Science and Herbarium

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
All Regions	All IBRA Regions	All Regions	Biodiversity informatics at the Western Australian Herbarium	36
Wheatbelt	Avon Wheatbelt, Swan Coastal Plain	Northern Agricultural, Avon, Swan, South Coast	Genetic and ecological viability of plant populations in remnant vegetation	44
Midwest, Goldfields, Wheatbelt, Swan, South Coast	Yaloo, Murchison, Geraldton Sandplains, Avon Wheatbelt, Coolgardie, Swan Coastal Plain, Mallee, Esperance Plains	Rangelands, Northern Agricultural, Avon, Swan, South West, South Coast	Genetics and biosystematics for the conservation, circumscription and management of the Western Australian flora	50
All Regions	All IBRA Regions, All IM-CRA Regions	All Regions	Herbarium collections management	34
All Regions	All IBRA Regions	All Regions	Interactive key and taxonomic studies of Myrtaceae tribe Chamelaucieae	30
South Coast	Esperance Plains	South Coast	Is restoration working? An ecological genetic assessment	29
Midwest, Wheatbelt, Swan, South Coast, South West, Warren	Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains	Rangelands, Northern Agricultural, Avon, Swan, South West, South Coast	Mating system variation, genetic diversity and viability of small fragmented populations of threatened flora, and other key plants of conservation importance	46
Pilbara	Pilbara	Rangelands	Molecular characterisation of stinking passionflower ( <i>Passiflora foetida</i> )	28



DBCRA Region	IBRA/IMCRA	NRM Region	Project Title	Page
Kimberley, Pilbara	Victoria Bonaparte, Northern Kimberley, Ord Victoria Plain, Central Kimberley, Dampierland, Great Sandy Desert, Carnarvon, Little Sandy Desert, Gibson Desert, Gascoyne, Central Ranges	Rangelands	Resolving the systematics and taxonomy of <i>Tephrosia</i> in Western Australia	38
All Regions	All IBRA Regions	All Regions	Seed biology, seedbank dynamics and collection and storage of seed of rare and threatened Western Australian taxa	49
All Regions	All IBRA Regions	All Regions	Strategic taxonomic studies in families including Amaranthaceae and Fabaceae ( <i>Ptilotus</i> , <i>Gomphrena</i> , <i>Swainsona</i> ) and other plant groups	31
All Regions	All IBRA Regions	All Regions	Systematics of the triggerplant genus <i>Stylidium</i>	41
All Regions	All IBRA Regions	All Regions	Taxonomic resolution and description of new plant species, particularly priority flora from those areas subject to mining in Western Australia	44
Kimberley, Pilbara, Swan, South Coast, South West, Warren	Victoria Bonaparte, Northern Kimberley, Central Kimberley, Dampierland, Gascoyne, Geraldton Sandplains, Swan Coastal Plain, Jarrah Forest, Esperance Plains, Warren	Rangelands, Northern Agricultural, Swan, South West, South Coast	Taxonomic review and floristic studies of the benthic marine algae of north-western Australian and floristic surveys of Western Australian marine benthic algae	42
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Taxonomy of selected families including legumes, grasses and lilies	39
All Regions	All IBRA Regions	All Regions	Taxonomy of undescribed taxa in the Ericaceae subfamily Styphelioideae, with an emphasis on those of conservation concern	37
All Regions	All IBRA Regions	All Regions	The Western Australian Herbarium specimen database	33
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	The Western Australian Plant Census and Australian Plant Census	32
Kimberley, Pilbara, Midwest, Swan, South Coast, South West, Warren	Victoria Bonaparte, Northern Kimberley, Central Kimberley, Dampierland, Geraldton Sandplains, Swan Coastal Plain, Jarrah Forest, Esperance Plains, Warren	Rangelands, Northern Agricultural, Swan, South West, South Coast	The Western Australian marine benthic algae online and an interactive key to the genera of Australian marine benthic algae	43
Midwest, Goldfields, Wheatbelt, Swan, South Coast, South West	Gascoyne, Geraldton Sandplains, Avon Wheatbelt, Jarrah Forest, Esperance Plains	Rangelands, Northern Agricultural, Avon, Swan, South West, South Coast	The population ecology of critically endangered flora	47
Midwest, Wheatbelt, South Coast, South West	Gascoyne, Murchison, Avon Wheatbelt, Coolgardie, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren	Northern Agricultural, Avon, Swan, South West, South Coast	Translocation of critically endangered plants	45

# Ecosystem Science

DBCRA Region	IBRA/IMCRA	NRM Region	Project Title	Page
Wheatbelt	Avon Wheatbelt	Avon	Advancing the hydrological understanding of key Wheatbelt catchments and wetlands to inform adaptive management	58
Wheatbelt, Swan, South Coast, South West, Warren	Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Esperance Plains, Warren	Northern Agricultural, Avon, Swan, South West, South Coast	Do hotter and drier regions harbour adaptive variation for climate change?	54
Swan, South West, Warren	Jarrah Forest, Warren	Swan, South West	FORESTCHECK: Integrated site-based monitoring of the effects of timber harvesting and silviculture in the jarrah forest	68
Pilbara, Midwest, Goldfields, Wheatbelt, South Coast, South West, Warren	Murchison, Geraldton Sandplains, Avon Wheatbelt, Coolgardie, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren	Wheatbelt, Rangelands, Northern Agricultural, South West, South Coast	Genetic analysis for the development of vegetation services and sustainable environmental management	70
South West	Swan Coastal Plain, Jarrah Forest	South West	Hydrological function of critical ecosystems	55
Swan	Jarrah Forest	Swan, South West	Hydrological response to timber harvesting and associated silviculture in the intermediate rainfall zone of the northern jarrah forest	69
South West, Warren	Jarrah Forest	Swan, South West	Identification of seed collection zones for rehabilitation	67
South West	Jarrah Forest		Investigating the causes of change in forest condition	53
Swan, Warren	Jarrah Forest, Warren	Swan, South West	Long-term stand dynamics of regrowth forest in relation to site productivity and climate	64
South West	Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren	Swan, South West, South Coast	Management of invertebrate pests in forests of south-west Western Australia	65
South West	Jarrah Forest, Warren	Swan, South West	Responses of aquatic invertebrate communities to changing hydrology and water quality in streams and significant wetlands of the south-west forests of Western Australia	57
Warren	Jarrah Forest, Warren	South West	Responses of terrestrial vertebrates to timber harvesting in the jarrah forest	62
Warren	Warren	South West	Restoring natural riparian vegetation systems along the Warren and Donnelly Rivers	61
All Regions	All IBRA Regions	All Regions	Taxonomy, zoogeography and conservation status of aquatic invertebrates	59
Warren	Warren	South West	Understanding peat wetland resilience: evaluating the impact of climate and land-use change on the hydrodynamics and hydrogeochemistry of peat wetlands in the Warren (Muir-Byenup) District	60
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Western Australian flora surveys	63
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Western Australian wetland fauna surveys	66

## Marine Science

DBCRA Region	IBRA/IMCRA	NRM Region	Project Title	Page
Kimberley	Bonaparte Gulf, Kimberley, Northwest Shelf, Cambridge-Bonaparte, Canning, King Sound	Rangelands	Distribution and abundance estimate of Australian snubfin dolphins at a key site in the Kimberley region, Western Australia	75
Pilbara	Pilbara, Pilbara (Off-shore)	Rangelands	Habitat use, distribution and abundance of coastal dolphin species in the Pilbara	74
Pilbara	Pilbara, (Nearshore)	Pilbara Rangelands	Improving the understanding of West Pilbara marine habitats and associated taxa: their connectivity and recovery potential following natural and human induced disturbance	77
Pilbara	Ningaloo	Rangelands	Interactive effects of fishing and climate change on coral reef fish populations	83
Pilbara	Pilbara, (Nearshore)	Pilbara Rangelands	Long-term monitoring in the area of the proposed Dampier Archipelago marine reserves	73
All Regions	All IBRA Regions, All IM-CRA Regions	All Regions	Marine monitoring program	79
Kimberley, Pilbara	Northwest Shelf	Rangelands	North West Shelf Flatback Turtle Conservation Program	81
Pilbara	Carnarvon, (Nearshore)	Pilbara Rangelands	The influence of macroalgal fields on coral reef fish	77
Kimberley	All IMCRA Regions	Cocos Keeling Islands, Rangelands	Understanding movements and identifying important habitats of sea turtles in Western Australia	78
Swan, South West	Pilbara, Carnarvon, Yalgoo, Geraldton Sandplains, Swan Coastal Plain, Warren	Rangelands, Northern Agricultural, Swan	Understanding the key ecosystem services provided by the seagrass meadows of Western Australia	72
Kimberley	Oceanic Shoals, Bonaparte Gulf, Kimberley, Northwest Shelf, Cambridge-Bonaparte, Canning, King Sound, Eighty Mile Beach	Rangelands	WAMSI 2: Kimberley Marine Research Program	82

## Fire Science

DBCRA Region	IBRA/IMCRA	NRM Region	Project Title	Page
Warren	Jarrah Forest	South West	Burning for biodiversity: Walpole fine-grain mosaic burning trial	92
All Regions	All IBRA Regions	All Regions	Development of a systematic approach to monitoring and reporting on the outcomes of prescribed burns and bushfires	85
Swan	Geraldton Sandplains, Swan Coastal Plain	Northern Agricultural, Swan	Evaluation of synergies among fire and weed management in urban biodiversity and fire management	86
Goldfields, Wheatbelt, South Coast	Yalgoo, Avon Wheatbelt, Coolgardie, Mallee	Wheatbelt, Rangelands	Fire regimes and impacts in transitional woodlands and shrublands	91
	Jarrah Forest	South West	Long term response of jarrah forest understorey and tree health to fire regimes	89

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
Kimberley	Northern Kimberley	Rangelands	North Kimberley Landscape Conservation Initiative: monitoring and evaluation	89
Midwest, Wheatbelt, Swan, South Coast, South West	Jarrah Forest, Mallee, Warren	Northern Agricultural, South West, South Coast	Understanding the changing fire environment of south-west Western Australia	87

## Kings Park Science

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
All Regions	All IBRA Regions, All IM-CRA Regions	All Regions	Conservation biotechnology	98
All Regions	All IBRA Regions	All Regions	Conservation genetics	95
Wheatbelt, Swan, South Coast, South West, Warren	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren	Northern Agricultural, Avon, Swan, South West, South Coast	Orchid conservation and recovery	97
All Regions	All IBRA Regions, All IM-CRA Regions	All Regions	Restoration science	94
All Regions	All IBRA Regions	All Regions	Seed science	93

## Perth Zoo Science

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
Swan, South West	Swan Coastal Plain, Jarrah Forest	Swan, South West	<i>Geocrinia</i> frog breed and rear for release program	105
Swan	Swan Coastal Plain	Swan	Behavioural observations of Perth Zoo collection animals for animal welfare purposes and establishment of baseline data	103
Midwest, Swan, South Coast	Geraldton Sandplains, Swan Coastal Plain, Jarrah Forest, Esperance Plains	Northern Agricultural, Swan, South Coast	Dibbler breed for release program	107
Swan	Swan Coastal Plain	Swan	Memory of recent actions in large-brained mammals ( <i>Elephas maximus</i> )	102
Wheatbelt, Swan, Warren	Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Warren	Northern Agricultural, Swan, South West	Numbat breed for release program	107
Swan	Swan Coastal Plain	Swan	Olfactory and auditory based behavioural enrichment for Perth Zoo's Asian elephants	102
Midwest, Swan, South Coast	Gascoyne, Murchison, Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren	Wheatbelt, Northern Agricultural, Swan, South West, South Coast	Survival and dispersal of black cockatoos in south-west Western Australia	108
Swan	Swan Coastal Plain	Swan	Using dataloggers to determine the effects of handling and temperature on packages travelling along Australian postage routes used to illegally transport native fauna	101

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
Swan, South Coast	Swan Coastal Plain, Mallee, Esperance Plains	Swan, South Coast	Western ground parrot husbandry	100
Swan, Warren	Geraldton Sandplains, Swan Coastal Plain, Jarrah Forest, Warren	Swan, South West	Western swamp tortoise breed for release program	106

## Rivers and Estuaries Science

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
Swan	Swan Coastal Plain	Swan	Alfred Cove eutrophication investigation: gaining insights to apparent eutrophication-related stress exhibited by seagrass in the Swan Estuary Alfred Cove Marine Park	117
Swan	Swan Coastal Plain	Swan	Algal blooms: investigations and control	116
Swan	Swan Coastal Plain	Swan	Application of FlowCAM® to biological monitoring in the Swan Canning Riverpark	120
Swan	Swan Coastal Plain	Swan	Apply acoustic technologies to investigate fish communities and movement	110
Swan	Swan Coastal Plain	Swan	Explaining foreshore vegetation die-off	119
Swan	Swan Coastal Plain	Swan	Incident investigations, response and advice	114
Swan	Swan Coastal Plain	Swan	Investigate habitat connectivity in relation to environmental flows and barriers	111
Swan	Swan Coastal Plain	Swan	Investigating fish communities as an indicator of estuarine condition	118
			Investigations of contaminants in the Swan Canning	113
Swan	Swan Coastal Plain	Swan	Model frameworks for estuarine reporting	121
Swan	Swan Coastal Plain	Swan	Seagrass monitoring and evaluation	115
Swan	Swan Coastal Plain	Swan	Swan Canning Water Quality Monitoring	112

## Remote Sensing and Spatial Analysis

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
Midwest	Yalgoo, Shark Bay	Rangelands	Dirk Hartog Island vegetation monitoring	128
All Regions	All IBRA Regions	Rangelands, Northern Agricultural, Swan, South West, South Coast	Remote sensing and spatial analysis for fire management	124
All Regions	All IBRA Regions, All IM-CRA Regions	All Regions	Remote sensing monitoring	126
All Regions	All IBRA Regions, All IM-CRA Regions	All Regions	Spatial analysis and modelling	125
All Regions	All IBRA Regions, All IM-CRA Regions	All Regions	Spatial data management	122

## Species and Communities

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
All Regions	All IBRA Regions, All IM-CRA Regions	All Regions	Ecological communities conservation and recovery	130
All Regions	All IBRA Regions, All IM-CRA Regions	All Regions	Fauna conservation and recovery	135
All Regions	All IBRA Regions, All IM-CRA Regions	All Regions	Flora conservation and recovery	133
All Regions	All IBRA Regions	All Regions	Off-reserve conservation	132
All Regions	All IBRA Regions	All Regions	Wetland conservation	129

## Ecoinformatics

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
All Regions	All IBRA Regions, All IM-CRA Regions	All Regions	BioSys – the Western Australian Biological Survey Database	138
All Regions	All IBRA Regions, All IM-CRA Regions	All Regions	Online GIS biodiversity mapping ( <i>NatureMap</i> )	139

