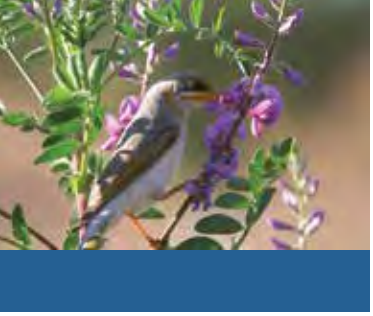


GOVERNMENT OF WESTERN AUSTRALIA

Department of **Biodiversity, Conservation and Attractions**

Biodiversity and **Conservation Science**

Biodiversity and Conservation Science Annual Research Report **2017–18**

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Images
Front cover main photo: Rowley Shoals. *Photo – Will Robbins/DBCA*

Front cover top photos left to right:
Yellow-throated miner on Ashburton pea. *Photo – Stephen Van Leeuwen/DBCA*
Mound spring survey. *Photo – Val English/DBCA*,
Ranger checking cage trap. *Photo – Judy Dunlop/DBCA*
Boodie joey. *Photo – Judy Dunlop/DBCA*

Back cover top photos left to right:
Banksia woodland Yanchep. *Photo – Jill Pryde/DBCA*
Montgomery Reef. *Photo – Will Robbins/DBCA*
Little Beach, Two Peoples Bay. *Photo – Stephen Van Leeuwen/DBCA*
Matuwa (Lorna Glen). *Photo – Judy Dunlop/DBCA*

Department of

Biodiversity, Conservation and Attractions

Biodiversity and Conservation Science

Annual Research Report

2017–2018

GOVERNMENT OF WESTERN AUSTRALIA

Department of **Biodiversity, Conservation and Attractions**

Biodiversity and **Conservation Science**

Director's Message

I am pleased to present our first research report as the Department of Biodiversity, Conservation and Attractions. On 1 July 2017, the Department of Parks and Wildlife was amalgamated with the Botanic Gardens and Parks Authority, Zoological Parks Authority and Rottnest Island Authority. A key focus area for the new department, as identified by the State Government, is to combine biodiversity science into one department to build and share biodiversity knowledge. In that context, the science functions of the previous agencies have been combined in Biodiversity and Conservation Science and this report reflects the activities and outcomes of the science work of the new department for the past financial year.

In forming Biodiversity and Conservation Science to provide science services to the whole of the department, we have established a new structure. Along with continuing the existing programs of Animal Science, Plant Science and Herbarium, Marine Science, Ecoinformatics, and Species and Communities, we have formed new programs in Fire Science, Kings Park Science, Perth Zoo Science, Remote Sensing and Spatial Analysis, and Rivers and Estuaries Science. The work undertaken in the previous Wetlands Conservation Program and the Biogeography Program has joined forestry research in the Ecosystem Science Program. A Biodiversity and Conservation Science Forum held in May showcased the diversity and high quality of science delivered by Biodiversity and Conservation Science, and provided an opportunity for staff and affiliated students to learn about the science projects undertaken.

A key activity this year has been to prepare a Science Strategic Plan for the department. Development of the plan drew on the knowledge and expertise of a range of departmental staff from science, operations, management and policy, to determine the key direction for science to support the policy and operational conservation management functions of the department. The plan was endorsed by Corporate Executive in June and was launched by the Chief Scientist, Professor Peter Klinken, in August. The plan articulates the key objectives of science against five of the six strategic intent statements for the department: Biodiversity and Conservation, Fire Management, Natural and Cultural Values, Our Community and Partners, and Our People. The science plan also links with state science priorities, as Biodiversity and Marine Science is identified in *A Science Statement for Western Australia* as a priority area for science in Western Australia where scientific knowledge is essential to ensure we conserve, appreciate and value add to the unique biodiversity found around us.

Throughout the changes and development of the strategic plan we have maintained our scientific research activity and outputs. Highlights for this year include a pilot translocation of hare wallabies to Dirk Hartog Island given the success in goat and cat eradication programs, the launch of the Banksia Woodlands Restoration book that is a culmination of many years research into restoration of Banksia Woodlands by scientists from Kings Park, flora translocation for species identified as a priority in the national Threatened Species Strategy, the completion of targeted surveys for rare flora and bilbies in the La Grange Irrigated Agriculture project area in the west Kimberley, and the discovery in Roebuck Bay of the first consistently used foraging area for flatback turtles. Species and Communities Branch staff have also provided considerable input to the drafting of Regulations to support the *Biodiversity Conservation Act 2016*. Most of our projects have been undertaken in partnership with conservation staff in the Parks and Wildlife Service, and from Perth Zoo and Kings Park, and with fantastic assistance from our volunteers.

I look forward to continuing to consolidate our new structure and furthering the delivery of excellence in applied science to support the conservation management of our diverse plants, animals and ecosystems for the benefit of all Western Australians. We will have an ongoing focus on partnerships and will strive to build additional relationships with universities, the resources sector, aboriginal land managers and NGOs. We also have a renewed focus on science communication and looking for new ways to share inspiring stories and connect people with our fascinating plants and animals and our unique natural places is a key objective.

Dr Margaret Byrne
Executive Director
Biodiversity and Conservation Science
November 2018

Contents

Service Delivery Structure

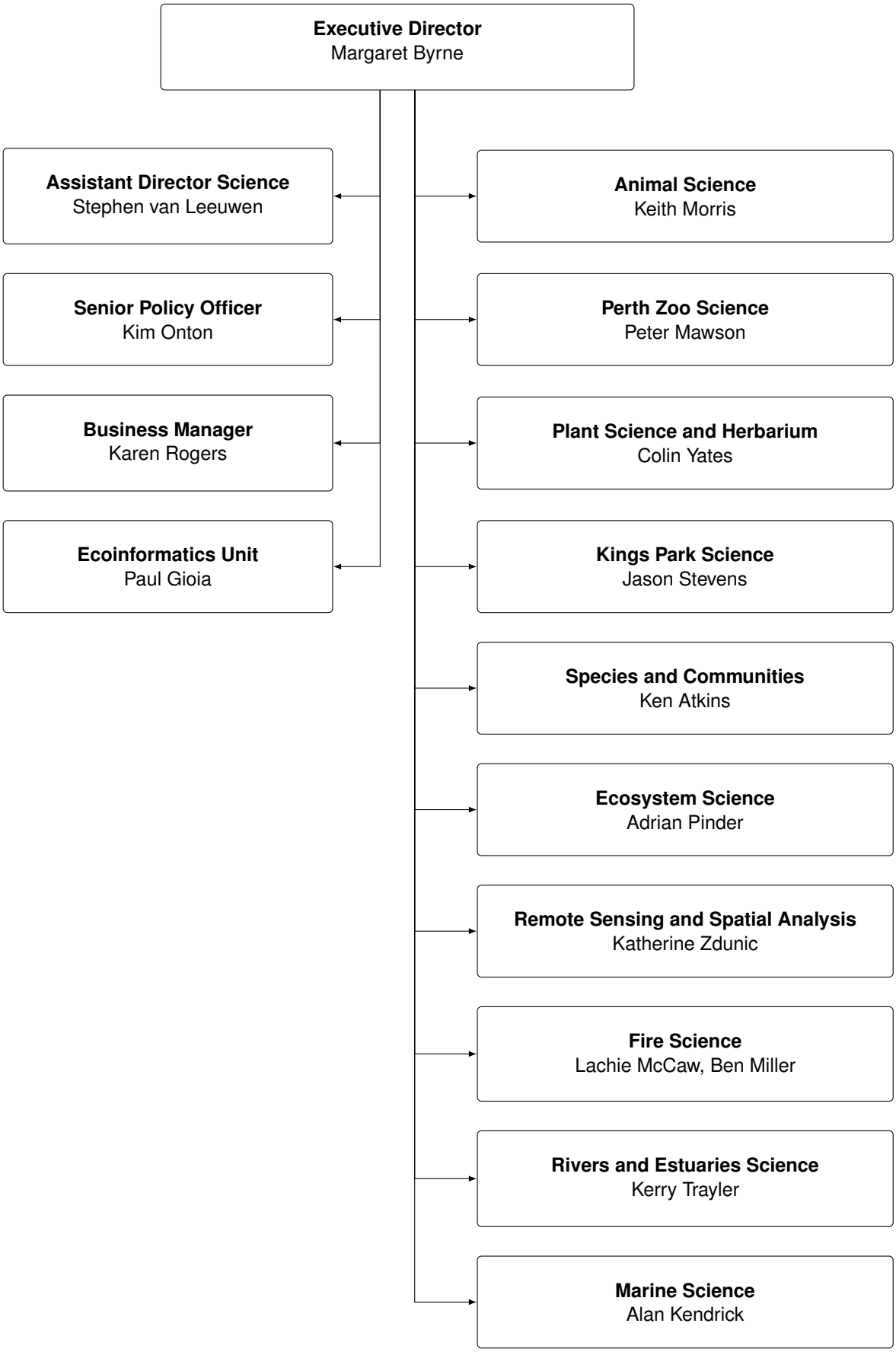
Science in the Department of Biodiversity, Conservation and Attractions is undertaken in accordance with the departmental Science Policy, where science refers to scientific research, scientific monitoring and science communication undertaken in relation to the biological, physical and social environments.

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.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Remote Sensing and Spatial Analysis
Katherine Zdunic
Fire Science
Lachie McCaw, Ben Miller
Rivers and Estuaries Science
Kerry Trayler
Marine Science
Alan Kendrick

Animal Science

Program Leader: Keith Morris 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.

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

SP 2017-001

D Pearson, A Friend, T Button, S Hill

Context

Carpet pythons are predators of a range of threatened mammal fauna, including the endangered Gilbert's potoroo (*Natator depressus*). Python predation can reduce adult survival and may curtail recruitment. This is particularly problematic when threatened mammals are confined by habitat availability or if housed in enclosures. 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 growth of 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 without management intervention, python predation was likely to cause potoroo extinction 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, trap 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

- Active searches for pythons were most successful at night; none were located during daytime searches; two pythons were obtained when they ate potoroos fitted with tail radio-transmitters.
- Five carpet pythons were surgically implanted with radio-transmitters and tracked within the enclosure, some had sizeable home ranges and two crossed through or over the enclosure fence.
- A trial of shelter box traps was undertaken and no pythons have been detected using them. Their elevation off the ground has prevented the many mammals in the pen from setting up dens in the boxes.
- A heat pad/battery/solar combination that could make the shelter boxes more attractive to pythons is under investigation.

Management implications

- Carpet pythons are predators of Gilbert's potoroo and some control of their activities in the Waychinicup National Park will reduce the incidence of predation events.
- The reduction of carpet python predation could result in an increase of potoroos within the enclosure.
- The results of the study could have application for controlling python predation of other threatened species.

Future directions

- Continuing searches will be undertaken to locate pythons and fit them with radio-transmitters. In particular, searches for male pythons should also detect female pythons during the spring mating season.
- Trials of the shelter box trap will continue, with the incorporation of heat pads and other possible attractants for pythons.
- Other potential python attractants will be examined that could aid in the capture and removal of pythons.

Dirk Hartog Island National Park Ecological Restoration Project – fauna reconstruction

SP 2016-030

S Cowen, C Sims, K Morris, K Ottewell, S Garretson, J Angus, K Rayner, M Page, A Burbidge

Context

The Dirk Hartog Island National Park Ecological Restoration Project (DHINPERP) 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. The establishment of populations of 12 mammal species and one bird species on Dirk Hartog Island (DHI) over a 12 year period is a key part of this project. To allow this to proceed, the sheep, feral goats and feral cats have been eradicated. Fauna translocations are planned to commence in September 2018. Prior to this, trial translocations of 12 banded hare-wallabies (*Lagostrophus fasciatus*) and 12 rufous hare-wallabies (*Lagorchestes hirsutus*) were undertaken in August 2017 to trial collection and transport techniques, and develop adequate monitoring protocols for use on DHI. This was succesful and planning is underway for larger numbers of hare-wallabies to be translocated in 2018, followed by the other species over the ensuing years. Genetic information on source populations has been and will be used to inform founder selection and genetic monitoring of released animals will inform ongoing management practices.

The aim of Stage Two of the DHINPERP is to re-establish up to 10 terrestrial native mammal species on DHI and establish up to two native mammal species that may have previously occurred there, along with healthy vegetation and ecosystem processes to sustain the islands biodiversity.

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 birds 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

- Genetic analysis was conducted on all natural and translocated populations of banded and rufous hare-wallabies. For both species, genetic diversity was low and there was significant genetic differentiation between the Bernier and Dorre island populations. The Bernier and Dorre islands banded and rufous hare-wallabies were mixed to maximise genetic diversity of the translocated populations on DHI.
- The trial translocations of the banded and rufous hare-wallabies was successfully implemented and all short-term translocation success criteria were met. Three of the four medium-term success criteria were also met.
- The only mortality recorded was a rufous hare-wallaby that most likely died of capture myopathy.
- Movement areas and home ranges were determined for the radio-collared individuals.
- When hare-wallabies were examined when trapped or having radio-callars removed, there was evidence of breeding (16 pouch young, lactating teats) and most individuals had recovered or exceeded the condition they were in when released on DHI.
- Planning for the translocations of larger numbers of hare-wallabies in September 2018 was commenced.
- The monitoring of the small vertebrates on DHI was undertaken in conjunction with the Global Gypsies.
- The covering of open wells on DHI to prevent animals falling into them, continued. Road signs warning the public about the presence of animals at night were obtained to reduce the risk of vehicles hitting translocated fauna and will be erected in July 2018.

Management implications

- Establishing large and viable populations of banded and rufous hare-wallabies (and the other species) on DHI will significantly reduce their risk of extinction and may lead to an improvement in conservation status for several threatened species.
- Hare-wallabies (and the other translocated species) undoubtably play a role in managing and improving ecosystem function, through grazing, browsing and endozoochory. There may be potential for the browsers and grazers that are established on DHI to control some of the weed species on the island.
- The presence of medium-sized mammals on DHI will ultimately lead to increased likelihood of interactions with the general public, especially with vehicles. Signs encouraging road users to drive slowly during hours of darkness will be erected in 2018.

Future directions

- Further translocations of larger numbers of banded and rufous hare-wallabies from Bernier and Dorre islands will occur in September 2018.
- Monitoring of future translocations will incorporate radio-tracking as well as other techniques that will continue to be trialled to refine an effective monitoring protocol for these species.
- A research project to study the impact of hare-wallabies and other translocated species on the vegetation and ecological function is being developed with The University of Western Australia.
- A health monitoring research project will be implemented in collaboration with Murdoch University.
- Planning has commenced for the translocations of additional species in 2019, possibly the dibbler, boodie and western barred bandicoot. Planning is also underway for the translocation of the western grasswren to DHI in 2020.
- Genomic analyses of dibblers, boodies and western barred bandicoots are underway and will be used to inform founder selection. Assessment of genetic diversity within and between western grasswren populations on Bush Heritage Australia's Hamelin Station reserve and the Peron Peninsula to inform source of founders will be undertaken as part of a PhD project.
- Population viability models of banded hare-wallabies, western barred bandicoots and dibblers are currently being developed in collaboration with The University of Western Australia and University of Sydney.

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, N Birch

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 regarded as one of the most significant threatening processes for this Vulnerable listed species. The development of the *Eradicat®* bait has provided the opportunity to control feral cats at a landscape scale in the southwest of Western Australia but questions remain as to the potential risks of broadscale cat baiting programs on northern quolls and other native carnivores in the Pilbara. The trial baiting program undertaken on the Yarraloola pastoral lease in 2015 demonstrated that the *Eradicat®* bait presents a low risk to northern quolls. Based on this evidence, annual winter baiting of cats with *Eradicat®* over 145,000 ha 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®* to target feral cats on Yarraloola.
- Assess the effectiveness of broad-scale aerial cat baiting to reduce feral cat populations 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.

Progress

- Sixty camera trap sites were deployed on both Yarraloola (baited) and Red Hill (reference site) for 25 nights, both before and after baiting in July 2017, to monitor changes in feral cat occupancy.
- Aerial baiting using *Eradicat®*baits was undertaken over 144,638 ha on Yarraloola in July 2017.
- Cat detections following the baiting were extremely low (0.4 cats per 100 camera trap nights).
- Northern quoll populations were monitored at 18 trapping sites at both Yarraloola and Red Hill in September 2017. Capture rates of quolls on both properties were higher due to the improved seasonal conditions. Capture rates of both male and female quolls were higher on Yarraloola in 2017 but the difference with those on Red Hill were not significant.
- There was no mortality of quolls during the baiting program as determined by camera trap surveillance of tethered baits, capture rates and fur analysis.
- To gain independent verification of the efficacy of baiting, 13 cats were captured and collared on Yarraloola prior to baiting in April 2018.

Management implications

- The lack of impact of *Eradicat®* on northern quolls in the Pilbara suggests that landscape control of feral cats using aerial baiting is possible in other parts of the Pilbara where quolls co-occur with cats.

Future directions

- The broadscale *Eradicat®* feral cat baiting program will continue over Yarraloola on an annual basis until at least 2019 with continued use of camera traps in a before-after-control-impact design to monitor the effect of *Eradicat®* baiting on feral cats at Yarraloola.
- Continue monitoring of northern quolls using established trapping sites at both Yarraloola and Red Hill to detect changes in population size as a response to on-ground management actions.
- Pursue registration of *Eradicat®* feral cat baits for operational use in areas where northern quolls are present.

Cat eradication on Dirk Hartog Island

SP 2014-003

D Algar, G Desmond, J Fletcher, N Hamilton, M Johnston, M Onus, C Tiller

Context

On Dirk Hartog Island (DHI), the largest island off the Western Australian coast, 10 of the 13 species of native terrestrial mammals once present are now locally extinct most likely due to predation by cats. The island was established as a national park in November 2009, which now provides the opportunity to reconstruct the native mammal fauna. DHI could potentially support one of the most diverse mammal assemblages in Australia and contribute significantly to the long-term conservation of several threatened species. Eradication of feral cats would be a necessary precursor to any mammal reintroductions.

Aims

- Facilitate native fauna reintroductions to DHI through researching feral cat behaviour and susceptibility to baiting programs, implementing a cat eradication program, and developing effective cat monitoring protocols that will allow success of eradication programs to be assessed.

Progress

- There was an estimated population of 439 feral cats (range of 309–503) on DHI prior to the eradication program commencing. Cat removal was completed in 2016 with the last cat trapped in the northern zone in October 2016.
- Deployment of detector dogs in southern zone (2016) and northern zone (2017) and seasonal surveillance monitoring in 2017, indicates the absence of cats.
- Extinction models suggest there is less than a 1% probability that feral cats persist on DHI following last year's surveillance surveys.

Management implications

- Fauna reconstruction on DHI can only occur following cat eradication. Cat eradication will also assist the conservation of the extant fauna, including three threatened taxa. There is global interest in the outcomes of this project and the techniques used. Transfer of the knowledge gained and technology, through the publication of papers and presentations, will have significant benefits for the successful control and/or eradication of cats on lands managed by the department and other agencies both nationally and internationally.

Future directions

- Draft a series of manuscripts for publication relevant to the overall program and techniques developed.
- The 2018 surveillance program will continue through winter and spring. If no further cat activity is recorded, eradication success will be declared and the reintroduction of native species will commence in late spring 2018.
- Undertake final surveillance monitoring for cat presence across DHI and determine probability of eradication.

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

SP 2013-005

M Cowan, B MacMahon

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

- Establish suitable methodology for use of camera traps to estimate the presence and relative abundances of native and introduced mammal's species in the south-west of Western Australia.
- Investigate the effectiveness of baited (active) and un-baited (passive) cameras set to inventory targeted species.
- Investigate and assess the most appropriate methods of image analysis and data storage.
- Develop analytical tools for interpretation of camera trap data.

Progress

- A tool has been developed in the programming language R to simplify the analysis of long-term systematic camera trap data. The tool can access data directly from CPW Photo Warehouse and performs a variety of statistical analysis, graphical outputs and data formatting.
- This project has provided the core data for introduced predator, numbat and woylie monitoring for the South West Fauna Recovery Project at Dryandra.
- An information sheet on assessing camera traps to census mammals has been prepared.
- A Microsoft Access database, CPW Photo Warehouse (Colorado Parks and Wildlife), which has regular updates and is freely available under an open source license agreement, has been identified as the most appropriate software to service much of the department's remote camera usage needs. The software is relatively straightforward to use and is designed to facilitate the capture, storage, analysis and summary of data collected from remote wildlife cameras.
- R scripts have been written to collate species accumulation data for work carried out at Dryandra and the effort for detection of the full assemblage of critical weight range species and above is now well understood in this landscape.
- Cusum, a method of cumulatively monitoring variance around a mean, is being investigated as a potential monitoring tool for individual species detections.
- Interpolated distributional mapping of all critical weight range species and above, along with species richness and abundance, has been completed for the main project area of Dryandra.
- Long term data from this project has identified that variation in detection rates with changes in seasonal mean temperatures is an important consideration in camera trap survey and monitoring designs.
- Preliminary investigation of on-track verses off-track data for some species highlights that independence of detections may be as high as 30 times greater for off-track detections than on-track, but this is highly

dependent on spacing of cameras.

Management implications

- Assessment of variation in detection rates over time for all critical weight range species from this project is providing essential data on monitoring population stability and trends. This same data is used to examine the effectiveness of control measures on introduced predators.
- The camera array at Dryandra now forms a reference location against which comparisons from equivalent camera arrays at Boyagin, Tutanning and a fenced satellite block at Dryandra, can be compared and assessed in relation to management actions and the effects on critical weight range fauna.
- Analysis has shown that camera traps are an effective tool for detecting a suite of species currently not adequately monitored by the Western Shield program. However, there is evidence that baiting camera traps can lead to detection bias for some species and this needs to be taken into consideration for monitoring and survey programs. There is also some evidence that when cameras are first placed in an environment, detection rates for some species are elevated. This may result from the novelty of a new object in an animal's environment. Other issues identified include an indication that external temperatures may have technical implications on a camera's capacity to be triggered and thus detection rates may be affected.
- 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 (models HC600 and PC900) are among the most effective commercially available camera traps for departmental requirements and currently remain recommended for use. It should be noted that technology is constantly changing in this field and improvements in performance and price are likely in the future. Differences in performance may have considerable ramifications for comparative data where camera models change over time.

Future directions

- Assessment of new models of cameras and variation in design to understand the potential implication on monitoring programs. Further development of the application for camera trap analysis to ensure it meets the primary needs of users. It is also intended to make this application accessible through a server to regional staff so that analysis and reporting on camera trap data can be both timely and consistent, with minimal effort. An analysis of conventional trapping data comparing Western Shield information to that from cameras over the same timeframes at Dryandra will be undertaken. A publication based on this project is in final draft and intended for submission in 2018.

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

SP 2013-001

C Lohr, K Morris, K Zdunic

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 and provide critical breeding sites for seabirds and sea turtles. Many islands are also 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 oil, gas and mining industries, means an increased likelihood that invasive species will colonise pristine islands. This project will develop 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 an island biosecurity model for prioritising biosecurity actions. The project will focus on the 600+ 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 Baysian Belief Network (BBN) software).

Progress

- Cost and efficacy of management actions database is under development.
- Pilbara islands habitat map was completed.
- Islands DSS graphical user interface and functionality was pressure-tested, and user manual prepared.
- Despite pressure-testing the Islands DSS software still had software bugs. A software engineer has been contracted on part-time basis by James Cook University and is working with departmental staff to resolve the remaining issues.

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

- Finish error-checking and pressure-testing the Islands DSS software.
- Finalise and publish Island DSS software, and user manual.
- Store software input files on the departmental online data catalogue.
- Use Islands DSS to draft an initial set of management priorities for Pilbara islands.
- Publish the methodology used to map habitats on the Pilbara Islands.

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 will aim 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

- An extensive dataset of bilby records in the Pilbara continues to be collated from existing sources and field surveys, and a survey of the Yandeyarra area detected the western-most bilby population documented in the Pilbara so far.
- A protocol for verifying bilby presence has been published. This describes the type of sign that can be used to confirm the presence of the greater bilby in comparison with sign that should be used only to flag potential presence. This publication provides advice on the application of the plot-based technique to systematically search for sign and produce data for the estimation of regional occupancy. The approach to estimate survey effort to assert bilby absence is also described as well as advice on aerial survey techniques.
- The analysis technique of abundance monitoring data using spatially explicit capture-recapture analysis continues to be developed and improved with the implementation of polygon and transect detectors.
- A calibration trial of the abundance monitoring technique was undertaken at a fenced reserve into which a known number of individuals were released. This trial proved the accuracy of the technique to measure numbers of individuals within populations.
- The population abundance monitoring technique using DNA extracted from scats quantitatively collected at populations in the field continues to be implemented.
- Trial fire management at a population in the Pilbara was implemented with controlled burns undertaken to protect the population from destructive hot wildfires.
- Talks and posters on this project were presented at the 2017 International Congress of Mammalogy in Perth and the 64th Annual Scientific Meeting of the Australian Mammal Society in 2018 in Brisbane.

Management implications

- Development of refined survey and monitoring techniques for bilbies in the Pilbara bioregion will enable standardisation and comparability in occupancy surveys and monitoring, and surveys to detect the presence or absence of bilbies, and provides a means of assessing the importance of habitat. The protocol can be used for broader state and national applications.
- Improved understanding of bilbies in the Pilbara and elsewhere in Western Australia enables improved habitat modelling and predictions of bilby distribution. This will inform future management of bilby populations and assist in the assessment of mining and development proposals.
- Use of a standardised technique for examining abundance of bilbies will provide reliable and comparable measures of numbers of animals within populations. It is recommended that scat samples for DNA extraction be stored and transported in tubes with silica gel beads and cotton wool to protect the sample, to ensure increased sample viability.
- Populations in the Pilbara are geographically isolated and consist of a small number of individuals, and they are likely to be vulnerable to threats, a key one being unmanaged fire regimes, indicating that fire management is an important aspect of managing habitat for bilbies.
- It is recommended that any surveys using remotely piloted aircraft (RPA) require ground-truthing of both positive and non-detections to determine false positive and false negative error. This technique shows future potential and will be further developed.

Future directions

- Continue development of modelling of the distribution of bilbies in the Pilbara, and ground truth sites to validate the resulting models.

- Continue to optimise RPA technology to survey for bilbies.
- Commence implementation of threat management with initial focus on fire management at selected populations with community and stakeholder engagement and support.
- Initiate population genetics project using existing bilby DNA library collected from population monitoring and opportunistically collected scats.
- Initiate diet analysis of surplus scats collected during population monitoring and opportunistically collected scats.

Genetic assessment for conservation of rare and threatened fauna

SP 2012-034

K Ottewell, M Byrne, S McArthur

Context

Genetic analysis of threatened species can provide important information to support and guide conservation management. In particular, genetic tools can be used to aid resolution of the taxonomic identity of species to determine whether they have appropriate conservation listing. At a population level, analysis of the genetic diversity present in extant populations provides information on genetic 'health' of threatened species and how this may be maintained or improved through management actions, leading to long-term positive conservation outcomes.

Aims

- Resolve taxonomic boundaries of Western Australian bandicoots (*Isoodon* sp.), particularly *I. auratus* and *I. obesulus* and their subspecies, to determine appropriate conservation rankings.
- Investigate the role of fauna underpasses in providing connectivity between quenda (*I. obesulus* ssp. *fusciventer*) populations impacted by main road construction.
- Assess the genetic diversity and genetic structure of extant populations of black-flanked rock wallaby (*Petrogale lateralis* ssp. *lateralis*) to inform future conservation management, including translocations.
- Use DNA barcoding to confirm species identifications.
- Investigate genetic diversity of translocated brushtail possums and their source populations at Matuwa (Lorna Glen).
- Contribute to taxonomic assessment of *Trichosurus vulpecula*, including resolution of Western Australian sub-species.
- Assess genetic diversity, genetic structure and cave use of ghost bat (*Macroderma gigas*) populations in the Pilbara.
- Assess species composition and individual relatedness of Hamelin Bay pilot whale stranding.

Progress

- Initial mt DNA sequencing of *I. obesulus*, *I. auratus*and *I. macrourus* was insufficient to fully resolve taxonomic issues and genomic analyses are being undertaken in collaboration with South Australian Museum. A population genetic analysis was conducted to designate 'management units' in Western Australian bandicoots using microsatellite data and a draft manuscript is being prepared.
- Population viability analyses of urban quenda populations impacted by road construction have been completed. This explored the long-term trajectory of populations with and without fauna underpasses, and impacted by an additional range of threats (fire, urban expansion, inbreeding). A manuscript has been published in *PloS One* and a further manuscript documenting quenda mating patterns in remnant populations is being prepared.
- Preliminary data analysis of genetic diversity and structure of wheatbelt and mid-north west rock wallaby populations has been completed. Genetic and population viability analyses of the first two translocations

of wheatbelt wallabies to Kalbarri National Park has been completed. Genetic analysis of a third Kalbarri translocation is currently being undertaken.
- Microsatellite analysis of ghost bat populations across the Pilbara indicated high connectivity with a low level of genetic structuring between the Hamersley and northern Chichester regions. Spatial analyses indicated ghost bats were detected most frequently between caves located within ~10 km. Temporal analyses indicated a small number of individuals used the same cave over a two year time period. Two reports have been prepared.
- DNA barcoding and microsatellite analysis of pilot whales stranded at Hamelin Bay has been completed.
- DNA barcoding was used to confirm species identity of several stranded cetaceans.
- Assessment of the genetic diversity of brushtail possums translocated to Matuwa compared with their source populations has been completed, including development of a population viability model. A scientific manuscript is currently in review.
- Tissue samples of Western Australian brushtail possums have been sent to the South Australian Museum for phylogenomic analysis

Management implications

- An Australia-wide phylogenetic assessment of *Isoodon. obesulus* and related species/subspecies has enabled a more informed evaluation of taxonomic boundaries, showing that *I. o. obesulus* is restricted to eastern and southeastern Australia, and identifying a range extension of *I. o. fusciventer* (Western Australia) into South Australia. This information has informed an evaluation of threat status by the Commonwealth for the eastern and Tasmanian sub-species of *I. obesulus*.
- Population viability analysis of quenda populations provides information to inform management of populations in the urban interface and demonstrates that the impact of fauna underpasses on population persistence is somewhat context-specific, but extinction risks are predicted to increase in populations without fauna underpasses.
- Genetic information on rock wallaby populations will enable evaluation of the current status of nearly all extant populations, including the assessment of the effectiveness of past management interventions, and will contribute to planning of future conservation actions. Assessment of the 2016-17 translocation of rock wallabies to Kalbarri National Park showed that establishing mixed populations of Mt Caroline and Nangeen animals at Kalbarri increased their genetic diversity relative to either source population, and genetic analysis of a juvenile animal in 2017 indicated successful reproduction between a Kalbarri male and a wheatbelt female, indicating no genetic barriers to reproduction and that mixing founder animals from different populations is an effective management strategy.
- Genetic analyses and a Population Viability Analysis of brushtail possums at Matuwa showed that low genetic diversity or inbreeding are not likely contributing to the small population numbers. Modelling suggests that if population size remains small then augmentation is required to maintain genetic diversity.
- Microsatellite genotyping of ghost bat scats has been successful and represents a novel approach to population monitoring of this species that is difficult to monitor with traditional methods. Genetic analysis indicated high connectivity of ghost bat populations across the Pilbara, with a low level of genetic structuring between the Hamersley and northern Chichester regions, providing information for environmental impact assessment. Spatial analyses indicated ghost bats were detected most frequently between caves located within ~10 km providing information on home range and dispersal distances.

Future directions

- Phylogenomic analysis of *Isoodon* spp. will be undertaken to formally resolve the species boundaries across the group. Analyses of historical (using museum skins) and contemporary genetic diversity will be used to document their recent evolutionary history.
- Quenda mating system manuscript will be finalised.
- Comparison of historic and contemporary population genetics of wheatbelt rock wallaby populations will be finalised to monitor genetic change and investigate impact of past management actions. Monitoring of the Kalbarri National Park translocated rock wallaby populations will be completed and a manuscript prepared.
- Manuscript on brushtail possum translocation to Matuwa will be finalised.
- Assessment of the taxonomy of brushtail possum subspecies will be completed in conjunction with South Australian Museum.
- Further sampling of Pilbara and Kimberley ghost bat populations will be conducted to extend analyses.

- Statistical analyses of the Hamelin Bay pilot whale whale stranding will be completed and a manuscript prepared.

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 (*Isoodon 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

- Genetic diversity and gene flow has been assessed amongst 42 quenda populations distributed through the Perth Hills and Swan Coastal Plain regions. Connectivity of quenda populations across the Perth metropolitan region is strongly associated with the presence of remnant vegetation, and to a lesser extent, the presence of low shrub vegetation. Quenda form four genetic clusters that are delimited by geomorphic features such as the Swan River and wetland boundaries. Populations north of the Swan River have low genetic diversity, suggesting low population sizes. A draft manuscript is well progressed.
- Genetic diversity, connectivity and generalised dissimilarity modelling analyses have been completed for three small mammal species (*Pseudomys chapmani*, *P. hermannsburgensis* and *Ningaui timealeyi*) in the Pilbara and show high genetic connectivity across the Pilbara landscape. Analysis showed that genetic diversity and genetic structure were not strongly associated with any one particular landscape element (rivers, mountains), and the reserve system did not harbor high genetic diversity relative to the surrounding landscape since genetic diversity was high across the region. A manuscript has been submitted to *Journal of Biogeography.*

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.

- Analysis of genetic diversity and structure of the three small Pilbara mammals provides information to manage the broader landscape to ensure effective maintenance of these species, and demonstrates 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

- Further landscape genetic analyses will be completed for quenda that will involve landscape resistance modelling to determine connectivity pathways across the Perth metropolitan region.
- Further analyses on Pilbara small mammals will be undertaken.

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

SP 2012-024

C Lohr, M Blythman, N Burrows, K Morris

Context

Operation Rangelands Restoration commenced in 2000 with the acquisition of Lorna Glen (Matuwa) and Earaheedy (Kurrara Kurrara) pastoral leases by the Western Australian Government. This 600,000 ha area lying across the Gascoyne and Murchison bioregions is now the site for an ecologically integrated project to restore ecosystem function and biodiversity in the rangelands. This is being undertaken in collaboration with the traditional owners. In 2014 Native Title (exclusive possession) was granted over Matuwa and Kurrara Kurrara.

The area around Matuwa once supported a diverse mammal fauna that was representative of the rangelands and deserts to the north and east. These areas have suffered the largest mammal declines in Western Australia. This project seeks to reintroduce 11 arid zone mammal species following the successful control of feral cats and foxes, and contribute significantly to the long-term conservation of several threatened species. Mammal reconstruction in this area will also contribute significantly to the restoration of rangeland ecosystems through activities such as digging the soil and grazing/browsing of vegetation, and assist in the return of fire regimes that are more beneficial to the maintenance of biodiversity in the arid zone.

The first of the mammal reintroductions commenced in August 2007 with the release of bilby (*Macrotis lagotis*) and wayurta (*Trichosurus vulpecula*). Another nine species of mammal are proposed for reintroduction over ten years. Between 2010-2012, mala, Shark Bay mice, boodies and golden bandicoots were translocated into an 1,100 ha introduced predator proof fenced enclosure. The intention is to use these as a source for translocations to areas of Matuwa outside the enclosure where cats have been effectively controlled, and ultimately the establishment of free-ranging self sustaining populations.

Aims

- Develop effective feral cat control techniques in a rangeland environment.
- Reintroduce 11 native mammal species to Matuwa by 2020, 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 rangeland restoration.

Progress

- Track and scat/DNA surveys have established widespread presence of bilbies across the Bullimore sand plain land system.
- A landscape scale camera trap system to identify threatened fauna and predator activity across Matuwa has been installed and is being used to monitor effectiveness of feral cat baiting.
- Feral cat reduction in 2017 was 30-40%. Cat baiting in 2018 compared the efficacy of aerial and ground baiting.

- Different monitoring methods for golden bandicoots and boodies inside the fenced enclosure were trialed.
- Ongoing presence and sightings of mala adults and juveniles were detected inside the enclosure.
- Presence of golden bandicoots at release sites outside the fence from the 2015 reintroduction has declined in the last 12 months. Juvenile bandicoots that escape through the fence and remain outside close to the fenced enclosure are persisting at low densities.
- A study to examine the use of warrens by related boodies inside the enclosure was undertaken to provide information useful for any translocations to warrens outside the fenced enclosure.
- Martu ranger groups continue to be involved in fauna monitoring activities.
- Analysis of 10 years of translocation and monitoring data is being undertaken.

Management implications

- Fauna reconstruction is an important component of threatened species conservation and broader habitat management and increases probability of species persistence through establishment of multiple populations where threats can be managed.
- 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 fauna in the rangelands.
- Sourcing founder animals from multiple locations has proven to be valuable in establishing and maintaining healthy genetic diversity in reintroduced species (e.g. brushtail possums).
- Increased involvement of traditional owner rangers with fauna monitoring will assist future collaborative management arrangements.

Future directions

- Development of further engagement and cooperation with traditional owners in management and monitoring activities.
- Ongoing monitoring of bilbies and possums outside the enclosure, and of bandicoots, boodies, mala and Shark Bay mice inside the enclosure.
- Ongoing translocations will be postponed until an Indigenous Land Use Agreement is negotiated and joint management arrangements finalised.
- Respond to ongoing presence of low density bandicoot population outside the fenced enclosure, with targeted small-scale reinforcement.
- Complete analysis of last 10 years of monitoring data.

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

- The fieldwork supporting this project and analysis of data has been completed. Preparation of a publication is under way.
- Results show there was only a negligible level of consumption of non-toxic baits by red-tailed phascogales and all radio-collared phascogales were still alive a minimum of six days after toxic baiting, by which time all baits in replicated trials had been consumed by other animals. These results indicate that red-tailed phascogales are at low risk of 1080 poisoning through *Eradicat*® operations in their habitat.

Management implications

- *Eradicat*® can be used with minimal non-target impacts 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

- Cats will be captured and fitted with GPS collars by a contractor to gather additional data on cat movement on the periphery of reserves for this project and to support the detector dog project by providing cats in known locations for use in assessing the value of cat detector dogs in feral cat control.

Conservation of south coast threatened birds

SP 2012-022

A Burbidge, A Clarke, J Lane

Context

Identifying the conservation requirements of threatened south coast birds, such as the Critically Endangered western ground parrot, the Vulnerable western bristlebird, the 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 western ground parrots and western bristlebirds, including interactions with predators, habitat requirements and response to fire.
- Increase the survival chances of the western ground parrot, western bristlebird and western whipbird 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.

- Characterise and map habitat critical to the survival of the Australasian bittern.
- Survey and monitor Australasian bittern populations and habitat to assist tracking current trends.

Progress

- Monitoring of western ground parrots after extensive fires in Cape Arid National Park and Nuytsland Nature Reserve continued and preliminary examination of the data suggests that abundance levels are stable.
- Ground parrot monitoring protocols are being further refined through use of audio recordings and analysis of trends in current data set.
- Assisted in finalising the recovery plan for the Australasian bittern in Western Australia.
- Completed modelling to predict future distribution of ground parrots in the face of climate change, and to assist in selection of translocation sites. A paper is currently in review.
- Book chapters dealing with western ground parrot and noisy scrub-bird were published in *Recovering Australian Threatened Species. A Book of Hope.*
- Two conference papers were presented.
- Progress has been made on developing Australasian bittern monitoring protocols through the analysis of audio recordings and refining of detection techniques.
- Camera trapping surveys have provided information on foraging behaviour and habitat preferences of Australasian bitterns.
- Continued monitoring surveys of Australasian bittern in critical breeding habitat in the Le Grand Unallocated Crown land after very hot fire damaged 80% of the wetland in November 2016.

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

- Finalise writing up of data on response to fire by bristlebirds and write up data on morphometrics of the western ground parrot.
- Continue to develop monitoring analyses and techniques, and finish writing up recent survey data.
- Identify knowledge gaps in the ecological requirements of the Australasian bittern to improve the conservation and management of the species.
- Continue to monitor key populations of Australasian bittern and their habitat so that on going 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 an threatened species under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999*. Funding from mining offset conditions are being used to gain a better understanding of quoll distribution, ecology, demographics and management requirements

in the Pilbara. There are two major components of the project: 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

- Improve understanding of northern quoll population distribution, ecology and demography in the Pilbara.
- Provide information to resource development companies that will allow appropriate management of mining sites to ensure the persistence of resident northern quoll populations.
- Plan, establish and implement a regional northern quoll monitoring program in the Pilbara.
- Develop an understanding of quoll habitat requirements and model predicted distribution in the Pilbara.

Progress

- Research priorities for the Pilbara northern quoll (as determined at 2013 workshop) were published in *Australian Mammalogy*.
- Quoll distributional data continued to be added to the Pilbara Threatened Species portal in NatureMap. Additional records from the Great Sandy Desert - Karlamilyi National Park have expanded the known range of northern quolls by several hundred kilometres.

Management implications

- Enhanced distributional data that is publicly available in an online repository will enhance decision-making relating to northern quolls in the Pilbara. Future monitoring of northern quolls can be aligned with the methods of the regional program, to enable regional comparisons of population trends and change.
- Sophisticated northern quoll population distribution maps can be used to predict the likelihood of occurrence, and inform management decisions. Areas without data collection have been identified as priorities for ground-truthing, and key populations likely to be impacted by future threatening processes have been determined.
- Results from GPS tracking of northern quoll suggests that impacts can be limited if known quoll habitat is not fragmented or destroyed by infrastructure developments.
- 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.

Future directions

- Regional monitoring will continue, including collection of additional presence records.
- Population genetics for Pilbara northern quolls will be assessed with a further 500 DNA samples to be analysed. This will reveal information about the important northern quoll conservation units, genetic diversity within the region and effective home range size.
- Paternal genetics of northern quoll offspring will be examined, to inform on relatedness and paternity of litter-mates.
- Investigation into the interactions between northern quolls and introduced species (including predators: feral cat, red fox, wild dog, and the invasive cane toad) will continue.
- Characterisation of northern quoll denning requirements will be undertaken with the view to protecting these key habitat features, or recreating them with artificial habitat.

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. By involving community organisations and environmental consultants, it extends cooperative partnerships with the community.

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 manuscript detailing a mark-recapture study of the graceful sun-moth as a prelude to assessing its conservation status was accepted for publication in *Records of the Western Australia Museum Supplement.*
- A review of all sun-moths in Western Australia, including the graceful sun-moth, was published in *Records of the Western Australian Museum*.

Management implications

- Previous assessments of the conservation status of the graceful sun-moth led to the species status being changed from Vulnerable to non-threatened (Priority 4).

Future directions

- Monitoring results up to 2017-18 will be combined with estimates of demographic parameters derived from mark-recapture studies to ensure that the population is stable and to confirm the appropriateness of the current conservation listing.
- Publication of habitat model and genetic results.

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 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 trialed 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

- Further develop the taste aversion bait and undertake operational trials of the population about to be exposed to invading cane toads.
- Research the expansion of the technique to cover other reptile taxa such as elapid snakes and blue tongue lizards.
- Monitor quoll and goanna populations on toad infested Adolphus Island to understand how these populations persist and the likely impact of toads on other Kimberley islands.
- 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

- An operational trial of helicopter dropped taste aversion baits was undertaken in November 2017. Before and after trapping of quolls was not conclusive in terms of the baits impact, but may reflect the particular population dynamics of quolls when trapping was undertaken. Further analysis is currently underway.
- Surveys and camera arrays have been maintained on Adolphus Island to monitor quoll and goanna populations following the arrival of toads on the island. Both have persisted in the presence of cane toads.
- A total of 30 cane toads were fitted with radio-transmitters and tracked to determine where they survive during the dry season. They exhibit higher survival rates over the dry season without any access to water, by hiding in steep creek banks or down goanna burrows. This is significant as it contradicts other research that suggests they need to rehydrate at least every three days and that this characteristic can be used to prevent their spread on islands and into the Pilbara.

Management implications

- Operational trials of the taste aversion bait have provided hope that we will be able to save large numbers of quolls and leave viable populations in the landscape that can reoccupy vacated habitat. It also has ramifications for preventing the loss of genetic diversity in quoll populations.
- The monitoring techniques developed on Adolphus Island will assist with the monitoring of other Kimberley islands for the arrival of toads and their impacts on native fauna.
- The involvement of Wunamal-Gaamberra and Balanggarra rangers and Traditional Owners in the research means that the results have been shared with the land-holders and co-operative work can potentially occur on native title lands in the future.

Future directions

- Continue to refine the taste aversion bait by investigating the best season and time of day to drop baits, and ways to make the baits more palatable to quolls and more likely to invoke taste aversion (such as improving the olfactory characteristics of the bait). Run operational trials at other sites in the north and central Kimberley.
- Adapt the bait and 'teacher toad' (use of small toads to induce taste aversion) with other taxa such as goannas, elapid snakes and blue tongue lizards.
- Finalize research on where cane toads survive over the dry season to allow more informed appraisal of the 'waterless barrier', proposed by some academics to stop toads spreading from the Kimberley into the Pilbara.

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

SP 2003-005

D Algar, N Hamilton

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 is continuing with the objective of further enhancing bait uptake. Chemical synthesis of several compounds that elicit a chewing response by cats has been achieved. In addition, natural sourcing of these compounds is being undertaken to reduce costs of production. One of the main ingredients of the bait matrix is being evaluated against an alternative, in a series of pen trials, to test whether bait palatability and also longevity can be improved.
- Analysis of GPS radio-collar data is being conducted to assess whether bait encounter rate can be increased by modifying bait deployment.
- Refinement of the trapping technique to minimise risk to non-targets yet maintain effectiveness in feral cat capture is ongoing. A Standard Operating Procedure for cat trapping is now being developed and a manuscript drafted for publication.
- An encapsulated 1080 toxin bait (*Hisstory*) was tested in the Kimberley as a baiting option where non-target species (e.g. northern quoll) may be considered at risk from the 1080 direct injected *Eradicat*®baits. This study has led to research into the development of a bait that also minimises the risk to wild dog/dingo hybrids while maintaining its effectiveness for feral cat control.
- Work continues on improving and refining several cat lure options. A collaborative project is being undertaken with Phillip Island Nature Park (Victoria) to investigate visitation and re-visitation rates to olfactory attractants.

Management implications

- Development of effective baiting methods across climatic regions will ultimately provide efficient feral cat control at strategic locations across the state and lead to conservation benefits.
- Successful eradication of feral cats from a number of islands off the Western Australian mainland has occurred over the past ten years (i.e. Hermite, Faure and Rottnest islands), allowing the persistence of the native fauna on these islands and enabling effective reintroductions of mammals where appropriate. Eradication of cats on Dirk Hartog Island and Christmas Island, and the techniques developed during the course of these programs, will significantly improve the conservation of biodiversity in Western Australia.

Future directions

- Continue refinement of bait medium to improve bait consumption by feral cats.
- Analyse baiting effectiveness at the various research sites and refine the method of operation where necessary to optimise baiting efficacy.
- Further investigate bait consumption by non-target species and devise methods to minimise risk (e.g. toxin encapsulation).
- Refine and optimise cat lure options.

Gilbert's potoroo recovery plan

SP 1996-008

A Friend, S Hill, T Button

Context

Gilbert's potoroo (*Natator depressus*) is the world's rarest marsupial. Since its rediscovery in Two Peoples Bay in 1994, implementation of actions under a series of recovery plans has resulted in the establishment of two new populations near Albany: one on Bald Island and the other inside a 380 hectare enclosure protected from foxes and cats. A catastrophic bushfire at Two Peoples Bay in October 2015 rendered 90% of potoroo habitat there uninhabitable and killing 60% of known individuals. The current objectives of the project are the establishment of another island population with science–based assessment of the likelihood of success, to measure the rate of recovery of burnt habitat at Two Peoples Bay and to collect demographic data in all populations, followed by population viability analysis to inform future management options.

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

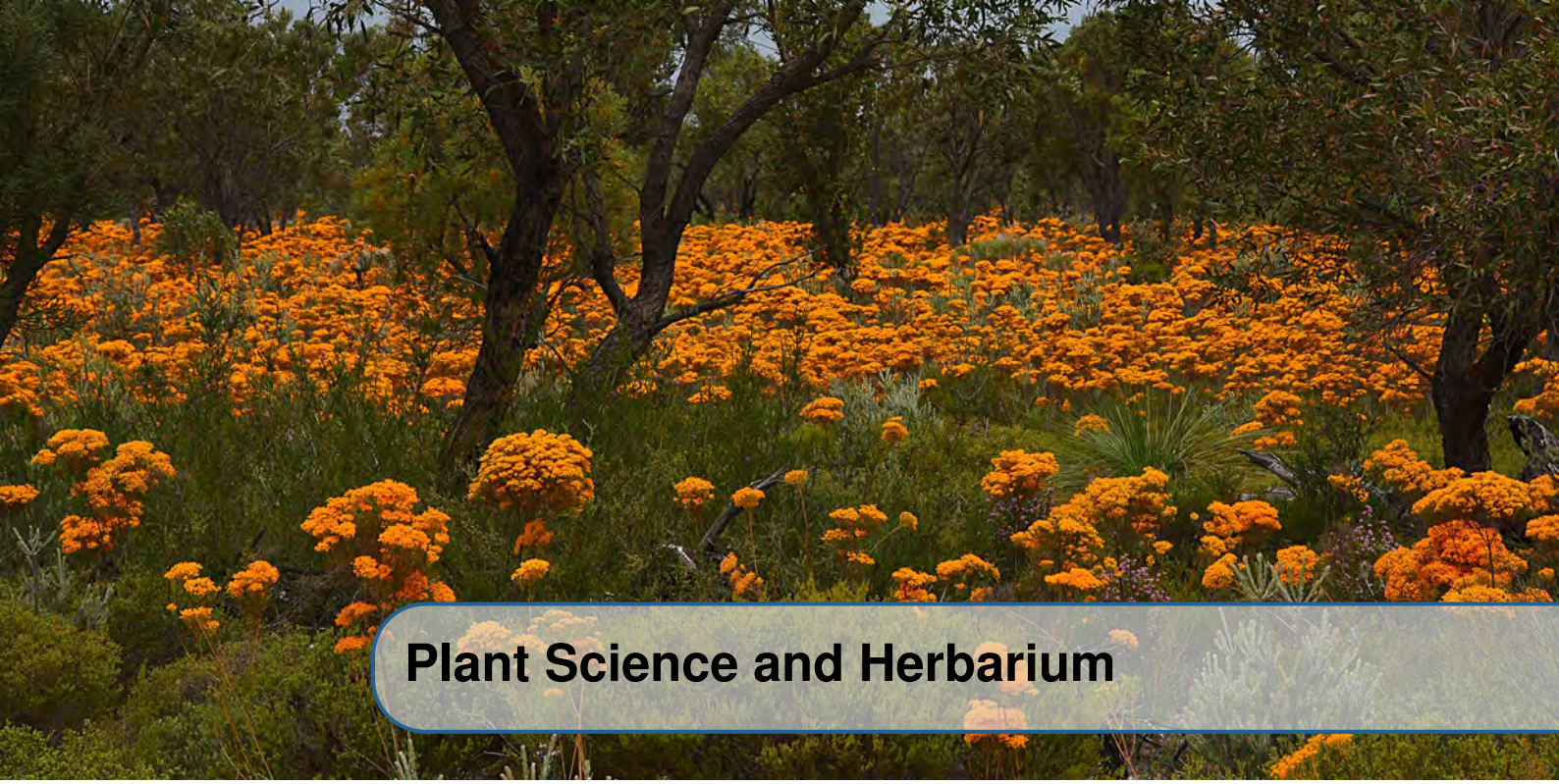
- GPS tracking of surviving potoroos at Two Peoples Bay in November 2017 showed that two years after the fire, individuals were already exploring burnt habitat well away from their unburnt refuge.
- Assessment of Middle Island in the Recherche Archipelago as a translocation site was undertaken during 2017-18 through a program of seasonal habitat assessment and two trial translocations, in winter 2017 and late summer 2018.
- In each trial, four potoroos were released on the island and monitored intensively by daily radio-tracking, GPS logging and weekly trapping. Faecal samples collected during trapping were analysed by a mycologist and spore types recorded. Success criteria were established to provide an assessment of the island as suitable for a full translocation: survival of 75% of the trial animals four weeks after release on the island, and body weight of all animals within 10% of release weight after four weeks. The success criteria were met in both trials and a full translocation has been approved.

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 (TPBNR) population that was impacted by fire.
- While islands provide safety for potoroos from introduced, and in some cases, native predators, careful prior evaluation of habitat suitability and in particular the adequacy of food resources is critical.
- 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

- Undertake analysis and publication of potoroo population demographics to determine future monitoring needs at all sites.
- Implement full translocation to Middle Island (Recherche Archipelago) and continue monitoring to evaluate success.



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 *Passsiflora 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 *Passiflora foetida* to *Passiflora* species native to Australia and to commercial varieties.
- Characterise Pilbara populations relative to less invasive populations to identify any signal of adaption.

Progress

- Samples were obtained from herbarium specimens of *P. foetida* at Missouri Botanical Garden for genetic analysis, including 117 samples from across the native range in South and Central America as well as a number of related species to be used as outgroups for analysis.
- Collections were made from 85 samples representing the invasive range in Western Australia, Queensland and Northern Territory.
- DNA has been extracted from all samples and the first set of samples is undergoing whole genome sequencing.

Management implications

- Information on the potential taxonomic entities and origin of *Passiflora foetida* in the Pilbara is essential to inform identification of putative control agents from the natural range and guide the search for putative control agents.
- Information on local adaptation within invasive populations is important to understand the dynamics of invasion and determine the effectiveness of potential control agents.

Future directions

- Complete collection of samples for genetic work from across study populations and the native range.
- Commence genetic analyses and generate initial results to clarify weed's taxonomic identity and invasion history.

Is restoration working? An ecological genetic assessment

SP 2016-015

D Coates, 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

- Leaf and seed collections from restored and remnant populations have been completed for *Hakea nitida, Melaleuca acuminata, Banksia media* and*Acacia cyclops*, and are in progress for *Eucalyptus occidentalis*.
- All laboratory work has been completed for *H. nitida, M. acuminata, B. media* and*A. cyclops*.
- Comparison of genetic diversity and differentiation among restoration and remnant populations of *A. cyclops* shows restoration populations have similar levels of genetic diversity and are not differentiated. A manuscript is in review with the journal *Restoration Ecology*.
- Comparison of genetic diversity and differentiation among restoration and remnant populations of *M. acuminata* shows restoration populations have similar levels of genetic diversity and are not differentiated. Mating system parameters are also similar among restoration and remnant populations. A manuscript is in review with the journal *Ecological Restoration*.
- Genetic diversity and mating system analysis shows that diversity is maintained in restoration populations of *B. media* and pollen dispersal is occurring across restored populations, and between restoration populations and remnant populations. Mating system parameters are also similar among restoration and remnant populations. A draft manuscript has been prepared.
- Genetic diversity, mating system analysis and pollinator observations in *H. laurina* shows that diversity is maintained in restoration populations and pollen dispersal is occurring across restored populations mainly through insect pollinators. A draft manuscript is in preparation.

Management implications

- Comparable genetic parameters in restored and remnant populations of *A. cyclops* and *M. acuminata* indicate that restoration practices have been effective in establishing initial ecological and genetic viability in the remnant populations.
- Restored Gondwana Link populations of these species have been founded using local germplasm with high genetic diversity and have mating systems comparable to those of remnant reference populations.
- Recruitment in restoration sites is likely to be the next challenge for management of restored populations of the study species.

Future directions

- Genetic analysis of *E. occidentalis* will be completed.
- Papers on each of the study species will be 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 200 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.
- 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 *Cryptandra* (Rhamnaceae), *Isopogon* (Proteaceae), *Pimelea* (Thymelaeaceae) and two genera of Myrtaceae have been submitted to *Nuytsia*.
- Papers on *Hysterobaeckea* and *Hypocalymma*(Myrtaceae) have been published in *Nuytsia*.
- Papers on a new subtribal classification of Chamelaucieae, *Hypocalymma* and *Scholtzia* are in preparation.
- Updates have been made to the interactive key to Myrtaceae tribe Chamelaucieae.

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 new genera where required.
- Submit papers on *Hypocalymma, Scholtzia* and the new subtribal classification (Myrtaceae).
- Complete articles for a special issue of *Nuytsia* planned for 2020.

Climate change risks for biodiversity and ecosystem function in species-rich shrublands

SP 2012-021

C Yates

Context

Correlative bioclimatic models are the primary tool for predicting the impacts of projected climate change on south-west Western Australia's globally renowned, species-rich shrublands (kwongan). These models have many untested and limiting assumptions. Empirical and experimental studies investigating the relationship between climate, ecohydrology and population dynamics are needed to develop better and more realistic mechanistic models for predicting the impacts of climate change on kwongan.

Aims

- Quantify seasonal patterns of water input, storage and distribution in the soil profile for shrubland sites of contrasting soil depth in relation to rainfall and plant water use.
- Quantify diurnal and seasonal patterns of plant water use among selected species from two major woody plant guilds (surface-water dependent sub-shrubs; groundwater-dependent shrubs and small trees) for shrubland sites of contrasting soil depth.
- Quantify the effects of decreased rainfall and increased air temperature on plant species ecophysiology and demography, identifying potentially lethal thresholds.
- Quantify plant demographic behaviour (survivorship, growth, fecundity) among selected species from two woody plant guilds for shrubland sites of contrasting soil depth.
- Apply a simulation modelling framework that links climate, soil water dynamics, plant water use and demographic response to investigate potential impacts of climate change on plant species and communities.

Progress

- Two scientific manuscripts describing the results of climate manipulation experiments are being revised.

Management implications

- Under projected warmer and drier climates for the south-west of Western Australia there are likely to be declines in species richness and changes in composition of kwongan toward lower stature more drought tolerant species. Decreased rainfall and increased temperature has been shown to reduce woody species germination, seedling survival, growth and plant survival along with flower and fruit production in mature vegetation. The magnitude of these changes varied among species from different plant functional types and was greatest in parts of the landscape where soil water is most limiting. Management should continue to focus on mitigating the risks and effects of interacting threatening processes, maintaining the genetic diversity of species to maximize potential for evolutionary adaptation, maintaining or enhancing ecological connectivity to maximize potential for species migration and identify the location of potential refugia where conditions remain suitable for the most vulnerable species to persist.

Future directions

- Publish results from climate manipulation experiments in scientific journals.

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

- Papers describing a new species of *Chamaescilla* and *Ptilotus* have been published in *Nuytsia*.
- Paper resolving the *Ptilotus gaudichaudii* complex published in *Australian Systematic Botany*.
- A paper describing new species of *Ptilotus* has been submitted to *Nuytsia* and a further paper resolving the *P. nobilis* complex has been submitted to *Australian Systematic Botany.*
- Three papers have been submitted for the 50th year edition of *Nuytsia*.
- A paper describing a new *Ozothamnus* has been published in *Taxon*.

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 provided 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* 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, M Falconer, E Wood-Ward, S Coffey, T Macfarlane, K Knight

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 datasets, 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. Until now plant censuses have been only state-based, which has made it difficult to obtain authoritative information on what species occur in Australia as a whole, to obtain accurate national statistics, and to deal with 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 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.

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 consensus.

Progress

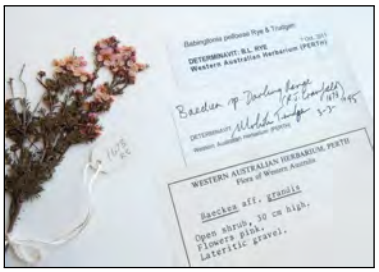
- 337 plant names (307 formally published and 30 informal names) were added to WACensus.
- 1,159 other edits were made to the WACensus.
- WACensus updates were regularly distributed to 255 registered Max users.
- An APC update list covering all newly published and informal (phrase) names, including synonymy, for the period 2014-2016 was processed and returned to Canberra.
- The final review of all currently known taxa in Western Australia for the family Orchidaceae is in progress.
- Contributed to discussions on agreed standard distributional categories for the APC, this is intended to reflect taxon distributions at the national level and indicate whether populations in a given jurisdiction are native, naturalised, or a combination of both.
- Addition of 106 new names to the Australian Plant Index (the source data for APC) as part of 996 edits (which also included data on synonomy and publications) as the State's contribution to this national cooperative database.

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 (departmental 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, the Australian Plant Census (National Species List), e-flora of Australia and the Australasian Virtual Herbarium.

Future directions

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



The Western Australian Herbarium's specimen database

CF 2011-110

J Percy-Bower, K Knight, M Falconer, R Gillen, E Wood-Ward, S Coffey

Context

The Western Australian Herbarium's 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 all the Herbarium's collections, enabling curation of the collection and providing core data for *FloraBase* and departmental decision support systems and research.

Progress

- Addition of 11,486 records to WAHerb, including 811 Priority Flora and 147 Threatened Flora. The following projects and significant collections were databased: Pilbara Biological Survey, South Western Australian Transitional Transect, Forestcheck Monitoring Program, G Byrne and K Syme collections.
- Regularly provided customised specimen data requests (species lists and label data) to departmental officers, researchers and the public.
- 83,393 specimen records were edited during this period as part of activities aimed at ensuring the collection is scientifically valid, up-to-date and aligned with the department's conservation codes.

Management implications

- WAHerb represents the most comprehensive database on 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 herbarium specimen records to maintain currency and connectivity between the Herbarium collection, the Western Australian Plant Census (WACensus) and external databases, including AVH and ALA.

Herbarium collections management

CF 2011-105

K Knight, C Parker, J Huisman, J Percy-Bower, R Rees, S Coffey, M Falconer, E Wood-Ward, M Hislop, R Davis

Context

The Western Australian Herbarium collection provides the core resource for knowledge of the State's plants, algae and fungi. The collection is growing constantly, through addition of new specimens representing new taxa and new records of existing taxa. The collection is maintained to a high standard, and provides the department and the community with the fundamental resource that provides knowledge of the diversity, distribution and abundance of plants throughout Western Australia.

Aims

- Fully document and audit the diversity of Western Australia's plants, algae and fungi.
- Maintain in perpetuity a comprehensive, adequate and representative research and archive collection of specimens of all taxa in these groups occurring in Western Australia.
- Contribute to, support and service the research, conservation and decision-making activities of the department.
- Contribute to, support and service taxonomic research by the world's scientific community.

Progress

- Addition of 11,486 specimens (including 811 Priority Flora and 147 Threatened Flora specimens) to the collection, which now stands at 791,006, a 1.47% increase in holdings.
- Loans and exchanges: loans outward–17 loans consisting of 104 specimens; loans inward–12 loans consisting of 668 specimens; loans returned to the Herbarium–42 loans consisting of 574 specimens; loans returned to their home institutions–54 loans consisting of 2,310 specimens; exchanges inwards–139 specimens; exchanges outwards–5,446 specimens including 28 requests for destructive sampling.
- Tasks managed by collections staff with the assistance of volunteers were as follows: mounting and labelling 8,039 specimens; validating the name and occurrence of 913 incoming specimens for lodgement; repackaging ca. 1,500 fungi specimens; processing backlog of A. Start's vascular parasite/host collection in preparation for databasing; entering data for 464 specimens into Max database format; added printed collection information to 7,939 pre-accessioned and accessioned specimen backlogs.
- The most significant projects accomplished were the distribution of the specimens from the closed Pilbara Regional Herbarium through the duplicate program, rehousing the fungi specimens collection from the Manjimup Herbarium and a focus on preparing the cryptogamic backlog for databasing.
- Volunteer participation was significant, totaling 10,843 hours, which is equivalent to ca. 6.2 full time employees. Twenty volunteers were recruited bringing the total working at the Herbarium to 65.
- Maintained the Reference Herbarium facility, which has 15,102 specimens representing 11,841 taxa as well as adding or replacing 282 specimens. This resource was used by 1,190 visitors to identify plant specimens during this period.
- Research collection was accessed by 878 visitors to study taxa or help with flora identification.
- Provided 124 high resolution scans of Herbarium specimens to departmental staff and industry consultants to aid in the identification and location of known and new populations of priority and threatened taxa, and to scientists for research purposes.

- Scanned 178 Types for the Global Plants Initiative, where Western Australian Herbarium Type specimens are now accessible to the world's scientific community for study.
- Significant collections lodged included industry surveys, regional staff surveys, Pilbara Biological Survey, Fortescue Valley Survey and collections from M Barrett and G Byrne.
- The Herbarium Identification Program provided identifications to a range of clients and specialises in taxa and specimens that clients find challenging. Our most significant clients included departmental staff, other government agencies, environmental consultancies, regional herbaria and the public.
- Educational role continued with staff providing tours of the Herbarium for departmental staff, tertiary institutions, environmental consultancies, community groups and the media.

Management implications

- Maintenance and curation of the Herbarium collections provides an authoritative inventory of the plant biodiversity of Western Australia underpinning flora conservation and 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.

Future directions

- Continue to maintain the collection to an authoritative standard for all users.
- Continue to review and document collections management policy and procedures, to effect efficiencies and reflect modern herbarium practices, and where applicable make these available on the Herbarium webpage.
- Recruit a sustainable number (approx 20 per year) of volunteers to assist in key Herbarium functions.
- Merge the incoming Manjimup fungi collection with the Herbarium research collection.
- Curate the lichen collection, focusing on rehousing the collection based on best practice principles.

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, currently holding data on over 792,000 specimens. It is the sole source of specimen data used by *FloraBase*. Imagebank is the Herbarium's image collection, currently containing data and files for nearly 74,000 images.

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

- Maintenance of the *FloraBase* application and content continued, including upgraded infrastructure, regular *Nuytsia* sub-site updates to support ongoing journal releases, and six other bug fixes for *FloraBase*.
- Maintenance of Imagebank continued, including a fix for auditing processes, corrections to the way the application interacts with WAHerb specimens and better download options.
- Maintenance of WAHerb continued, including major overhauls to the management of comment data, both for the specimen as a whole, and specifically for identifications, and eight other bug fixes for WAHerb.
- Maintenance of the Publishing System continued with 24 bug fixes supporting changes to WAHerb, WACensus, OIM infrastructure, flora statistics handling and more.

Management implications

- *FloraBase* allows the community and department staff to retrieve the most recent information on the name, features, status and distribution of the 13,867 currently recognised native and naturalised Western Australian vascular plant taxa and 2,572 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

- Complete an overhaul of the display of Imagebank images in *FloraBase*.
- Restart the maintenance of *FloraBase's* search data, derived from the Descriptive Catalogue and enhanced to support algae, fungi, lichens, mosses and slime moulds, as part of *FloraBase* 3
- Upgrade the mapping interface to make better use of modern mapping tools, and link to related tools, such as *NatureMap* and ALA.
- Implement a major revision of *FloraBase*, providing better decision-making support for tablets and phones and using ALA infrastructure, where suitable, to maximise the reuse of authoritative resources available across the Australian biodiversity information network.
- Add new content, including flora treatments from ALA's eFlora project.
- Commence a project to migrate WAHerb to a new collections management system.
- Develop further standards to facilitate and participate in national and international bio-infrastructure projects, such as ALA and GBIF, and common departmental online services.

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 foreshadowed significant changes to the classification of the epacrids at the generic level. This means that all taxa of West Australian epacrid flora currently assigned to *Astroloma* (27

taxa), *Coleanthera* (3) and *Croninia* (1) will be transferred to *Styphelia*. Also to be transferred are 108 taxa currently placed in *Leucopogon,* which represents approximately one half of the State's total for that genus. A forthcoming paper will formalise the transfer of all of the previously described species to *Styphelia.* Once the latter is published, a start can be made on the task of describing the phrase name taxa of *Styphelia* (i.e. in the new expanded sense) that are currently listed under *Leucopogon,* many of these being short range endemics of conservation significance. This project will therefore continue to describe new taxa in *Styphelia* and *Leucopogon* as well as other genera in the subfamily Styphelioideae.

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 which may be geographically restricted.

Progress

- A paper updating the taxonomy of the genus *Brachyloma* was published in *Nuytsia*.
- A paper describing a new threatened species of *Styphelia* has been accepted by *Nuytsia*.
- A collaborative nomenclatural paper is near completion and will formalise the transfer to *Styphelia* of species currently in *Leucopogon, Astroloma, Coleanthera* and *Croninia.*
- Collaborative papers dealing with the taxonomy of two natural groups (comprising 10 species in total) of western *Styphelia* are well advanced and will be published after the nomenclatural paper mentioned above.
- A paper describing two anomalous and geographically restricted new species of *Styphelia* is well-advanced.
- A new phrase-name taxon, *Styphelia* sp. Stirling Range was added to the census.

Management implications

- The epacrids, of which *Leucopogon* constitutes by far the largest genus, 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 *c.* 400 species of herbs and shrubs. Sixty-three taxa are currently recognised in the Eremaean and Northern Botanical Provinces of Western Australia; including 28 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 the 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 the Northern Territory (for the *eFlora of Australia*).
- Prepare identification tools, including an electronic key to the genus Australia-wide.
- Contribute to international phylogenetic research on *Tephrosia* and allied genera.

Progress

- One new taxon was recognised for Western Australia (*T.* sp. Durack River; Priority 1).
- One species was formally published in *Nuytsia.*
- One species has been submitted for formal publication in *Australian Systematic Botany.*
- A series of papers formally describing new species of *Tephrosia* in northern Western Australia are in preparation.
- 93 samples for molecular analysis (for *c.* 43 Western Australian taxa) were processed and distributed to overseas collaborators.
- Field work was conducted across the Kimberley region resulting in the collection of 161 voucher specimens and 54 spirit samples for the Western Australian Herbarium, 138 samples for molecular analysis, and 85 seed accessions for the Western Australian Threatened Flora Seed Centre.
- All *Tephrosia* specimens submitted to the Western Australian Herbarium were examined and had their identifications confirmed or corrected, thus maintaining the accuracy of *FloraBase*.
- The currency and accuracy of the *Tephrosia* collections in the Reference Herbarium and ImageBank were maintained, to facilitate taxon identification by stakeholders.

Management implications

- Providing names, scientific descriptions, illustrations and identification tools for the various *Tephrosia* in Western Australia will enable industry and conservation practioners 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 the 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 the Northern Territory, revise descriptions where necessary, and publish papers describing new species.
- Conduct field work in central Australia and the Northern Territory.
- Commence production of a revisionary treatment of *Tephrosia* in Western Australia and the Northern Territory for the *eFlora of Australia*, and commence production of a key to all *Tephrosia* taxa Australia-wide.

Taxonomy of selected families including legumes, grasses and lilies

SP 2011-001

T Macfarlane

Context

Successful conservation of the flora requires that the 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 *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* (Potamogetonaceae; formerly *Lepilaena*): a genus of aquatic plants that have been difficult to identify has been studied from all Australian herbarium specimen holdings and species boundaries have been defined. A paper describing one new Western Australia species (*A. hearnii*) was published. Study of specimens and field research continued, resulting in recognition of another new Western Australian species for which a draft description was prepared.
- *Wurmbea* (Colchicaceae): continuing work on describing thirty new species, including preparation of plates of photographs.
- Hydatellaceae: a paper on the molecular phylogeny and genetic variation in *Trithuria australis* was finalised for submission for publication.
- Poaceae: continuing research collaboration on *Neurachne* and the evolution of C_4 photosynthesis. Work continued on a paper reporting an unusual virus genetic signature in *N. minor*.
- *Thysanotus* (Asparagaceae): review of the taxonomy of the twining species, the *T. patersonii* group, continued with extensive field work that revealed previously unknown species. Species definition continued using collections, photos made during field work and DNA analysis. Preparation of paper including photographic plates proceeded. Numerous new species have been recognised from this work. A paper was prepared for submission describing a new species of *Thysanotus* from Kalbarri.
- *Lomandra* (Asparagaceae): paper being drafted on *L. suaveolens* group. Poor seasonal conditions prevented completion of this project.
- Asparagales: a paper was published on tepal apex trichomes (TAT), a neglected taxonomically useful flower feature in this order of plants. Collaboration continued on a wider, Melbourne-based, phylogenetic study of the Asparagales order of families, which involved extensive field work in south western Australia.
- Anarthriaceae: a paper was drafted with colleagues on reproductive morphology of Western Australian endemic plants in *Hopkinsia* and *Anarthria*.

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.

Future directions

- Complete and submit papers describing new species of *Wurmbea*, *Thysanotus, Lepilaena* and *Lomandra*. Conduct appropriate field searches for species or populations 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 in *Rytidosperma* (Poaceae) and reviewing the *T. patersonii* group, *Arthropodium* and *Lepilaena* in Western Australia.
- Publish information on selected plant groups for general audiences.

Temperature thresholds for recruitment in south-west Western Australian flora

SP 2010-003

A Cochrane

Context

Germination is one of the fundamental biological activities vital to persistence in obligate-seeding species. Climate directly influences germination and seedling growth, with temperature arguably the most important climatic variable after moisture, since it synchronises germination to environmental conditions most suitable for seedling establishment. Although species have climate preferences, knowledge of basic physiological tolerances is lacking for most native species. Assessing direct physiological constraints on recruitment (e.g. upper and lower temperature limits for germination) and early seedling growth may assist our understanding of the impact of warming temperatures on the persistence of plant species at the limits of their geographic range.

Aims

- Determine temperature thresholds for germination in south-west Western Australia flora.
- Identify potentially 'at risk' plant species and incorporate this data into the modelling of impacts of climate change on 'at risk' species.
- Utilise this data as a basis for developing management response options, including fire management and flora translocations.

Progress

- Paper submitted to *Plant Biology* describing effects of temperature on germination in 20 endemic species from the Ravensthorpe Range.
- Paper submitted to *Folia Geobotanica* describing effects of temperature on germination in eight herbaceous species from south-west Western Australia.

Management implications

- Information on the temperature niches for germination of Western Australian species will assist in climate change vulnerability and adaptation planning, and ecological restoration. Incorporation of seed biology knowledge into the translocation and management of threatened species will increase recovery success.

Future directions

- Finalisation of a manuscript currently in preparation on the influence of heat shock on overcoming dormancy in a threatened Western Australian *Acacia* species, will complete this project.

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 genus *Stylidium* 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

- The identity of *c.* 600 Western Australian Stylidiaceae specimens was confirmed or corrected at the Western Australian Herbarium and the South Australian Herbarium, improving the quality of data available through *FloraBase* and the *Australasian Virtual Herbarium* (*AVH*).
- Type material and associated data for one undescribed species from south-western Australia was obtained, and another undescribed species was opportunistically discovered.
- Two taxonomic papers and one collaborative pollination paper (led by Prof. Scott Armbruster at Portsmouth University) were progressed.

Management implications

- Taxonomic research continues to improve our knowledge of Western Australia's triggerplant flora, with baseline data on the distribution, habitat requirements and conservation status of each species informing on-ground conservation efforts.

Future directions

- Prepare *Stylidium* phylogeny for publication.
- Commence flora writing using the digital Flora platform.
- Conduct targeted field work and validate the identity of herbarium records to underpin research publications and improve the quality of data available through *FloraBase* and *AVH*.

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 for north-western Australia, documenting this biodiversity.

Progress

- The second book in the series documenting the marine flora of north-western Australia, *Algae of Australia: Marine Benthic Flora of North-western Australia, 2. The Red Algae*, has been published by the Australian Biological Resources Study and CSIRO Publishing. The book includes descriptions of 158 genera and 351 species, with seven genera and 88 species newly described. All species are illustrated, with over 1,350 figures (many in colour).
- Several field surveys of the marine algae of the Perth region have been undertaken, resulting in the description of the new species *Rosenvingea australis* and *Tricleocarpa australiensis*, plus recognition of an undescribed species of the red algal genus *Champia.*
- A revised edition of *Marine Plants of Australia* has been submitted to the University of Western Australia Press. This edition is greatly expanded and includes descriptions and colour images, mostly *in situ*, of over 600 marine plants.
- Addition of 1,233 new specimens of marine benthic algae to the Herbarium collection.

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 paper describing a new species of the red alga *Champia*, collected from Cape Peron.

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

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 158 genera and 351 species of north-western Australian red algae have been prepared for uploading to *FloraBase*.
- Numerous additional *in situ* and microscopic images of marine algae have been taken. Over 50 new images have been uploaded to ImageBank/*FloraBase*.
- Data for 1,233 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.

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

- Finalise 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, M Hislop, B Rye, T Macfarlane, R Butcher, R Davis, S Dillon, K Shepherd, 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 1,218 putatively new and undescribed taxa on Western Australia's vascular plant census, 581 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 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

- 14 threatened, rare or poorly known species in *Brachyloma*, *Lasiopetalum*, *Hysterobaeckea*, *Ptilotus*, *Tecticornia* and *Tephrosia* were formally published in *Nuytsia*, and a potentially threatened species of *Ozothamnus* was published in *Phytotaxa*.
- Targeted field work to obtain Type specimens or data for 12 undescribed, conservation-listed taxa was successfully completed.
- 21 additional papers describing conservation-listed taxa were submitted for publication in *Nuytsia*, of which 19 are contributions to a special issue being planned for 2020.
- 11 new phrase-names were added to the WACensus. These taxa are rare or poorly known. Recommendations were also made for an additional eight taxa be added to the Threatened and Priority Flora list for Western Australia.
- Examination of collections at the Western Australian Herbarium led to the discovery of new populations of the following conservation-listed species: *Angianthus newbeyi*, *Chthonocephalus muellerianus*, *Epitriche demissus*, *Gnephosis setifera*, *Hemigenia tichbonii*, *Levenhookia pulcherrima*, *Melaleuca similis*, *Millotia dimorpha*, *Philotheca* sp. Mukinbudin, *Ricinocarpos*sp. Eastern Goldfields and *Stylidium*sp. Moora.
- A presentation on the importance of integrating taxonomic research with conservation efforts in Western Australia was given at the *Systematics 2017* conference in Adelaide.

Management implications

- The provision of names, scientific descriptions, illustrations and associated data will enhance the capacity of conservation and industry practioners 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

D Coates, M Byrne, C Yates, M Millar, T Llorens, S McArthur, N Gibson, J Sampson

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 reproductive output, progeny fitness, mating system variation and genetic diversity in relation to habitat fragmentation for *Eucalyptus wandoo* has been published in *Frontiers in Ecology and Evolution*. Higher levels of soil electrical conductivity were strongly associated with greatly reduced fruit set, suggesting significant sub-lethal effects of secondary soil salinity on reproduction. Levels of pollination were surprisingly high in small populations but probably involve high levels of self-pollination, leading to low seed set in small populations. Increased seedling survival in certain populations was attributed to increased nutrient availability in the agricultural matrix.
- Analysis of reproductive output, mating system variation, progeny fitness and genetic diversity in fragmented populations of *Eremaea pauciflora* has been completed and a paper is in preparation.
- A paper on pollen dispersal and mating system in *Banksia nivea* subsp. *uliginosa* is in press in *Biological Journal of the Linnean Society*, and a paper on reproductive biology and demography in *B. nivea* subsp. *uliginosa* is in revision following review.

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.
- Levels of secondary soil salinity should be assessed and monitored in high-value vegetation remnants in agricultural landscapes. The *E. wandoo* study revealed that low to moderate levels of soil salinity can have highly significant sub-lethal effects on reproductive output, which are likely to translate to reduced population viability.

Future directions

- Finalise a paper on mating system variation and reproductive output in *E. pauciflora*.
- Finalise papers on genetic diversity, reproductive biology and demography in *B. nivea* subsp. *uliginosa*.

Translocation of critically endangered plants

SP 2001-004

L Monks, R Dillon, D Coates, C Yates

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

- Infill planting was completed for translocations of five Critically Endangered plant species at six sites.
- Four new translocation sites were set up for three species (*Banksia cuneata, B. brownii* and *Vertivordia spicata* subsp. *squamosa*).
- Final demographic monitoring was undertaken for *Acacia cochlocarpa* subsp. *cochlocarpa* at translocation and natural sites, with the monitoring to be used to develop a Population Viability Analysis (PVA) model for this subspecies.
- Drafting of a publication on flora translocation success criteria is underway.
- Contributed to the drafting of new Australian guidelines for plant translocations.
- Paper on experimental approaches to improving establishment success and persistence of threatened plant translocations has been published in the *Australian Journal of Botany*
- Assisted District and Regional staff plan and implement a range of flora translocations. Planning commenced for experimental translocation of *Lambertia orbifolia*.

Management implications

- Translocations lead to improved probability of persistence for threatened flora, particularly Critically Endangered plant taxa. Ongoing monitoring of translocations is providing information on the success of methods used and the probability of long-term success. Close collaboration with District and Regional 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 PVA, mating system analysis and genetic variability analysis, will ensure completion criteria are adequately addressed and resources can be confidently 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

- Continue the planting of experimental translocations of Critically Endangered and other threatened flora where further translocations are deemed necessary, and continue monitoring translocations and evaluating success.
- Develop alternative criteria for evaluating success such as PVA, mating system and genetic variability analysis.
- Complete a review and meta-analysis on translocation methodologies, outcomes and success in Western Australia.
- Publish paper on translocation methods and *L. orbifolia* PVA study.

- Develop PVA model for translocated and natural populations of *A. cochlocarpa* subsp. *cochlocarpa* using demographic data collected over past five years.
- Establish an experimental admixed population of *L. orbifolia*.

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

SP 2001-001

D Coates, 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

- Genotyping has commenced on seed extracted from collections from 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.
- Pollination studies have commenced 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.
- Fitness trait studies have commenced 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.
- A genetic diversity study and crossing study has commenced on the Critically Endangered *Schoenia filifolia* subsp *filifolia* and another subspecies to evaluate the level of genetic differentiation between subspecies and whether genetic rescue involving crossing between subspecies is a feasible management option.
- Seed collections have been completed for natural and translocated populations of *Lambertia orbifolia* to assess mating system variation and genetic variability, and benchmark mating system performance and genetic diversity in translocated populations.

Management implications

- Assessment of genetic variation 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* and *L. orbifolia*.

- Translocation programs for *B. brownii* should continue to mix seed collections from within the three eco-geographic regions, but translocations should not yet be established with seed mixes from different regions. Further translocations using seed collected from the now extinct eastern Stirling Range populations should be considered given the high levels of genetic diversity found in those populations.

Future directions

- Finalise data analysis and draft paper on the mating system in *S. affine* and *S. maritimum*.
- Finalise mating system and genetic diversity analyses on translocated and natural populations of *B. brownii* and *L. orbifolia.*

The population ecology of critically endangered flora

SP 2000-015

C Yates, D Coates, N Gibson

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 (Declared Rare 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.

Progress

- Continued monitoring the demography of the Critically Endangered *Verticordia staminosa* subsp. *staminosa* in relation to a drying climate in south-west Western Australia.
- Data collected from micro-climate sensor array across the Ravensthorpe Range and surrounds has been used to develop a new set of climatic layers at appropriate scales for modelling the distribution of short range endemics under the influence of a projected warmer and drier climate.
- A paper on fire response of Threatened Flora has been published in the *Australian Journal of Botany.*
- Continued demographic studies of Threatened Flora on the south coast to investigate the impacts of fire and disease.

Management implications

- Review and analysis of the fire response of Threatened Flora and the development of fields in the Threatened and Priority Flora database will assist in the design and delivery of improved fire management protocols.
- Micro-climatic surfaces for the Ravensthorpe Range and surrounds will assist with conservation planning for short-range endemics and Threatened Flora.
- Demographic studies investigating the impact of fire and disease for Threatened Flora on the south coast will provide information for ecologically acceptable fire return intervals and species recovery.

Future directions

- Begin analysis of long term monitoring data set collected for *V. staminosa* subsp. *staminosa* to investigate the effects of declining rainfall on recent population dynamics.

- Publish paper on the climate surfaces developed from the micro-climate sensor array in the Ravensthorpe Range.
- Continue demographic studies of Threatened Flora on the south coast.

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 329 seed collections (178 species) were banked at the Threatened Flora Seed Centre during 2017–18; 119 of these collections (66 species) were listed as Critically Endangered, Endangered or Vulnerable (Threatened Flora). 33 of these collections (27 species) were listed as Priority Flora.
- 131 germination tests were conducted.
- Seedlings of 12 Threatened Flora species were provided for translocation.
- The seed bank now contains 5,691 collections (1,881 taxa) representing 339 Threatened Flora, 724 Priority Flora and 817 key restoration species.

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 rare species 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 species for long-term conservation and use in re-introductions.
- Ongoing processing and storage of collection backlog.
- Germination testing, storage and monitoring of existing collections.
- Ongoing research into seed biology and seed storage behaviour of threatened plant taxa.

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

SP 1998-003

M Byrne, D Coates, N Gibson, R Binks, D Bradbury, B Macdonald, K Ottewell

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 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 level of differentiation and association with environmental variables in *Calothamnus quadrifidus* to assist in the taxonomic revision of the group.
- Determine the genetic differentiation between geographically disjunct populations of *Banksia biterax*.
- Determine the phylogenetic relationships among populations of *Banksia densa*.
- Determine the phylogenetic and population genetic relationships among the disjunct populations of *Eucalyptus virginea* and related species.
- Determine the phylogenetic relationships among Western Australia *Leptospermum* species and examine the level of differentiation 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 in *Eucalyptus salubris*.
- Determine the genetic relationships among Australian *Arivela* species and the genetic relationships in two species complexes.
- Investigate the role of lignotuber loss or gain in the evolution and conservation of eucalypt diversity, through deriving phylogentic relationships and quantifying genetic differentiation among a clade of eucalypts with obligate-seeder and lignotuber-resprouter taxa, using high density, genome-wide markers.

Progress

- Analysis of genomic data in the *C. quadrifidus* species complex is in progress to support taxonomic determinations, and to investigate the importance of phylogenetic history versus current climatic conditions on morphological variation. The patterns of genetic diversity and differentiation found were not fully explained by morphological subspecies, geographic location, climate or evolutionary history alone. Present-day distribution of genetic variation is likely to have been influenced by a range of factors.
- Genotyping and analysis of 10 populations of *B. biterax* from the Busselton and the Albany region using genomics and cpDNA sequences has been completed. The disjunct populations from Busselton and the Stirling Ranges are genetically distinct from the populations in the Albany region.
- Sequencing and analysis of 14 populations of *B. densa* with cpDNA gene regions has been completed, and do not indicate historical differentiation of the Corrigin population that exhibits some morphological variation.
- Collections of leaf samples from *E. virginea*, *E. relicta*, *E. lane-poolei*, *E. phylacis* and *E. decipiens* have been made, DNA extraction has been completed, genomic (DArTseq) sequencing has been undertaken and data analysis is in progress.
- Herbarium collections of 48 *Leptospermum* taxa have been made and shotgun sequencing is being undertaken.
- Genomic sequencing and analysis of 24 populations of *Seringia* species has been undertaken and results indicate no genetic differentiation between *S. elastica*/*S. elliptica*,and that *S. katatona* may be a hybrid species between *S. nephrosperma* and *S. elastica*/*S. elliptica*.

- Initial analysis identified two genetic lineages in *E. salubris* that also showed differences in specific leaf area. Analysis of 13 additional populations (22 in total) across the species' distribution has confirmed the presence of the two lineages with a south-west/north-east geographic orientation but with substantial overlap through the central area and geographically close populations belonging to different lineages. A paper is in preparation.
- Generic boundaries in *Cleome* have identified the Australian clade as the genus *Arivela*, and a paper was published in *Systematic Botany*. Relationships among *Arivela* have been determined using cpDNA and ITS sequencing and a manuscript is in preparation. Genomic sequencing of *A. viscoa* and *A. tetandra* has been carried out and analysis is being undertaken.
- A review of genetics and ecology of species that occur on Banded Iron Formations of the mid-west has been completed and submitted for publication in *Biological Reviews*.
- Samples from 178 individuals representing 45 populations of 11 taxa from the eucalypt series *Levispermae* have been analysed to establish phylogentic relationships and test for genetic differentiation associated with variation in lignotuber state.

Management implications

- Assessment of phylogeographic patterns and environmental associations in *C. quadrifidus* is informing taxonomic revision of the group.
- Identification of genetic differentiation between populations from three disjunct geographic regions of *B. biterax* confirms that populations in each region should be managed as separate lineages. Augmentation of the small Busselton populations should use seeds collected from the local populations only.
- Phylogenetic relationships among populations of *B. densa* suggest the morphologically different Corrigin population is possibly a distinct taxon, but this remains equivocal based on the cpDNA data.
- Population genetic analysis of relationships among disjunct populations of *E. virginea* will inform management of the populations, and will inform on the potential hybrid status of *E. phylacis* and its putative parental species.
- 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.
- Genetic assessment of several species of *Seringia* from the Kimberley will resolve whether the poorly known *S. exastia* is a distinct species and should remain listed as Declared Rare Flora.
- Resolution of lineages in *E. salubris* will provide a basis for potential taxonomic revision.
- Identifying genetic entities in *A. viscosa* and *A. tetandra* will provide a basis for taxonomic resolution of these species complexes.

Future directions

- Analysis of genomic data in *C. quadrifidus* and associations with environmental variables will be completed.
- Analysis of *E. virginea* and related species will be completed.
- Analysis of *Leptospermum* phylogeny will be completed.
- Fieldwork and population genomic analysis of several *Leptospermum* species complexes will be undertaken.
- Analysis of *Seringia exastia* complex will be completed.
- A paper detailing the genetic lineages in *E. salubris* will be finalised.
- Analysis of genetic relationships in *A. viscosa* and *A. tetandra* will be completed.
- Complete ecological and phylogenetic analyses on differences in lignotuber state among closely-related eucalypts.

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.

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

SP 2017-022

M Byrne, R Mazanec, K Ruthrof

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 endangered 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

- A paper on genetic adaptation to climate in marri has been submitted to *Molecular Ecology*. This genomic study of 23 populations across the range of marri, generating 10,000 SNP loci and showed low levels of genetic structure with isolation by distance in a north-south orientation. After controlling for population structure, analysis identified greatest variation explained by associations with temperature rather than rainfall or aridity. Variation occurred throughout the genome, and was found in gene coding and regulatory regions, including those 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 variation in provenance trials has been submitted to the journal *Evolution*. Analysis of 18 provenances and 170 families planted at Mt Barker and Margaret River has been undertaken for tree growth (height, basal diameter) and disease resistance (shoot blight). Growth and disease resistance both show moderate levels of genetic heritability. There were strong associations with the climate of origin (temperature, rainfall) showing high growth and disease resistance in southern coastal populations experiencing cool and wet climatic conditions.
- A drought experiment has been undertaken for seedlings from 12 provenances growing at 100% and 50% soil water holding capacity for four months over summer. Analysis of the data has commenced.
- Data analysis has been undertaken for a heatwave experiment where seedlings from eight provenances were grown under 'cool' (26 ℃ maximum) and 'warm' (32 ℃ maximum) growth conditions in a glasshouse and exposed to two consecutive five day heatwaves at either 40 or 46 ℃ in a fully factorial reciprocal temperature design. Leaf gas exchange, growth and leaf damage were monitored throughout the experiment under conditions where soil water content was maintained at field capacity. Results suggest that plants from cooler provenances exposed to the 46 ℃ heatwave experienced the most severe impacts on growth and had the highest levels of leaf damage.

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.

Future directions

- Analysis of glasshouse heatwave and drought experiments will be completed and papers written.

Hydrological function of critical ecosystems

SP 2016-005

J Rutherford, L Bourke, 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

- The Walyarta (Mandora Marsh) 3D conceptual model combining an interpretation of hydrogeophysics and hydrogeochemistry data was completed.
- A poster combining geophysics, near surface chemistry and environmental tracers to define critical ecohydrological management zones for the Walyarta mound springs was presented at the 3rd American Geophysical Union / Society of Exploration Geophysicists Hydrogeophysics workshop: Imaging the Critical Zone, in July 2017.
- A final report was completed on the *Hydrological Conceptualisation of the Walyarta Mound Springs*, which explains how the mound springs function and identifies the main hydrological processes that need to be considered for management, with the key findings being: mound springs are located on geological faults; the fine scale hydrogeology and structure of the Walyarta study area is locally unique, but retains the main elements and trends evident in the coarser scale West Canning Basin; the geochemical evolution of the groundwater reflects the coarser scale frameworks; local scale disruptions to flow encourages localised groundwater discharge, forming mound springs; and geochemical and isotopic fingerprinting of mound spring water indicates it is sourced from depths of up to 200 meters below ground level.
- A poster on understanding and managing the ecohydrology of the Brixton Street wetlands was presented at the 14th Western Australian Wetland Management Conference in February 2018.
- Groundwater and surface water level data collection was completed for a study of groundwater and surface water interactions in the Brixton Street wetlands.
- A ground hydrogeophysics (electromagnetics) investigation in the Brixton Street wetlands mapped shallow aquifer water quality to assess how freshwater wetlands are currently maintained and to identify potential

threats to biodiversity due to changes in hydrology and climate.

Management implications

- Construction of a conceptual hydrological model, that explains how the Walyarta mound spring TEC functions, will allow for prioritised hydrolgical data collection, reduce knowledge gaps and increase confidence in the development of future management actions. This information will enable the department to provide inter-agency advice on the need and extent of a groundwater protection zone for the mound springs.
- Hydroecological understanding obtained from the Walyarta project is transferable to other areas of the Kimberley Region and can be used in the preservation of other groundwater dependent TEC.
- Knowledge of hydrological functioning of the Brixton Street wetland complex will increase the department's capacity to develop management 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 inter-agency advice on the potential environmental consequences of developing land within the Guildford Clay Formation.

Future directions

- Undertake numerical modelling to develop a proof of concept on the role of geological faults at Walyarta.
- Complete journal articles that discuss the approach in development of a three dimensional (3D) conceptualisation of the Walyarta mound springs hydrology and how 3D modelling helps develop more effective investigation and monitoring programs that improve spring management outcomes.
- Develop Science Information Sheets to communicate major outcomes of the Walyarta study.
- Write an internal report and a journal article on the spatial and temporal variation observed in groundwater and surface water interactions in the Brixton Street wetland complex and recommend suitable monitoring and management actions.
- Integrate information obtained from Lucky Bay ground hydrogephysics and hydrogeochemical investigations to develop transfer criteria applicable and transferable to other areas in the Swan River Estuary (e.g. Ashfield Flats).

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

M Pennifold, A Pinder

Context

Aquatic habitats in the south-west of Western Australia are under increasing threat 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. At present, 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 the wetlands within the Muir-Byenup System Ramsar site.

This project has two components, 1) re-surveys of aquatic invertebrates in the Muir-Byenup System Ramsar site sampled in 1994 and 2004 and suites of wetlands further south sampled in 1993, addressing KPI3 of the 2014-23 FMP and, 2) periodic monitoring of high condition streams, with a focus on effects of the drying climate and forest management, addressing KPI1 of the 2014-23 FMP.

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

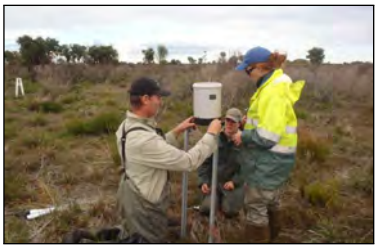
- Samples of aquatic invertebrates from Tordit-Gurrup Lagoon and Noobijup Swamp in 2016 were processed and specimens identified to determine response to acidification in these wetlands.
- Invertebrates collected from 20 forest streams in 2013 and 2016 were identified and AusRivAS condition ratings calculated. This information was included in a South West Catchment Council Regional Environmental Snapshot.
- Identification and taxonomic consolidation of historical macroinvertebrate data for Muir-Byenup invertebrates was completed.
- Collaborated with microinvertebrate taxonomists to reconcile taxonomic issues between 1996/97, 2003/04 and 2014/15 data for the Muir-Byenup wetlands.

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 (SPP2014-24), 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.
- Of the 21 stream sites sampled in 2013 and 2016 only one scored an AusRivAS condition band (band B - significantly impaired) lower than the 2005-2012 range for the same site. One site scored a higher band rating (band A - reference condition) than had previously been recorded at the same site. This indicates minimal change in the condition of ‘healthy’ streams in south-west forests during the life of the 2014-23 FMP to date (addressing KPI1).

Future directions

- Publish a paper comparing macroinvertebrate communities present in the Muir-Byenup wetlands in 1995/96, 2003/04 and 2014-16.
- Re-sample south-west forest streams in 2019 and publish report.
- Re-survey nationally important Warren Region wetlands previously sampled by Horwtiz in 1997.



South West Wetlands Monitoring Program (SWWMP)

SP 2015-002

J Lane, M Lyons, A Pinder, A Clarke, D Cale, Y Winchcombe, B Huntley

Context

Substantial decline in wetland condition has been observed across the south-west of Western Australia over the past 100 years, particularly in the Wheatbelt, almost certainly with ongoing loss of biodiversity. The most pronounced changes to wetlands have been associated with salinisation and altered hydrology following clearing

of native vegetation in catchments. Broad-scale clearing has largely ceased but hydrological and fragmentation processes will continue to be expressed for many decades. Changes in rainfall patterns are also resulting in significant changes to wetland hydrology, water chemistry and habitats.

While it is known that altered hydrological regimes and salinisation are major threats to wetland biodiversity, the relationships between physical expression and loss of biodiversity are poorly documented and poorly understood. Monitoring of wetland depth and water chemistry in the south-west began in 1977 to inform duck hunting management. After continuing at a reduced level following the ban on recreational duck hunting in 1992, the program was reinvigorated under the State Salinity Strategy in 1996, supplemented by intensive monitoring of fauna, flora, water chemistry and shallow groundwater at a subset of 25 wetlands. This project delivers information on the long-term trends and variability in key determinants of wetland character and condition.

Aims

- Analyse long and short-term changes in surface water quantity and quality, shallow groundwater levels and biodiversity at representative south-west wetlands in relation to threatening processes (particularly dryland salinity and reduced rainfall).
- Assess the effectiveness of catchment and wetland management.

Progress

- Depth and water quality monitoring was undertaken at 105 wetlands in September and November 2017, and following an exceptional rainfall event early in 2018.
- Water level loggers and rain gauges were maintained on 11 wetlands with high conservation values, especially for the threatened Australasian bittern. It is proposed that these data be used to model hydrological futures of these wetlands.
- Autumn salinity profiling of Lake Jasper was undertaken in 2018, and analysis shows that this iconic wetland although still fresh, is increasing in salinity.
- The 1977-2016 SWWMP report was completed.
- Analyses of 1978-2015 trends in water levels in south-west Western Australia wetlands were undertaken and a journal article drafted. The analyses have revealed a general drying trend in wetlands across this period, especially since the early 1990s.
- Water level monitoring of the Vasse and Wonnerup Estuaries and the Lower Vasse River wetlands continued to provide critical information for the management of the Vasse-Wonnerup System Ramsar site.
- Analyses of relationships between wetland character and aquatic fauna were completed and several reports were completed or are nearing completion.
- Aquatic invertebrate samples collected during the first Toolibin Lake fill event in more than 20 years were processed and a report is in preparation.
- Data analysis is underway for dominant overstorey trees on Wheatbelt wetlands.

Management implications

- Rainfall and water levels in south-west Western Australia are declining with adverse implications for wetland flora and fauna (such as the threatened Australasian bittern) and for the recreational value of wetlands. The SWWMP project has provided early warnings of changes in three critical determinants of wetland ecological character (depth, salinity, pH) and helped inform where to focus management. This project provided a long-term context against which to assess the significance of contemporary observations and enabled prediction of the effects of threatening processes and wetland management.
- Analyses of patterns in the composition of wetland fauna and condition of vegetation at representative wetlands will allow predictions of future impacts of altered hydrology and understand the trajectory of Wheatbelt wetland biodiversity generally. Communities in representative Wheatbelt wetlands are not undergoing strong directional change at present, but their responses to variation in rainfall predicts that longer-term shifts can be expected. These data provide a baseline for any future monitoring work.

Future directions

- Ensure SWWMP data and associated files are appropriately archived and available on corporate databases.
- Complete write-up of the 15 years of fauna and flora monitoring at the intensively monitored wetlands and archive data.

- Use results of long-term periodic water level, salinity and pH monitoring, continuous on-site rainfall and water level monitoring, and other datasets, to predict likely future senarios of wetlands important for the Australasian bittern and other fauna and flora under different climate scenarios.
- Focus ecological research and monitoring on Ramsar sites to enable the department to better report on their condition.

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

SP 2015-001

J Rutherford, L Bourke

Context

Changes in the hydrology of Toolibin Lake and the Lake Bryde catchments, due to land clearing, has resulted in these previously ephemeral fresh water 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

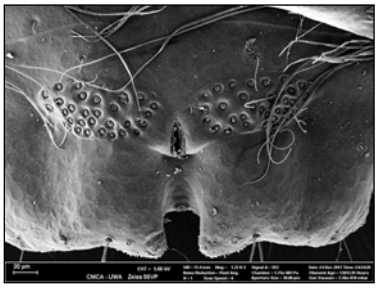
- Completed collection of groundwater and surface water data to study the 2017 Toolibin Lake episodic rainfall/lake inundation event. Commenced analysis and reporting of this data to assess the lake water balance and report on hydrological interactions and their response to evaporation, transpiration and groundwater pumping.
- Undertook and reported on a site audit and decommissioning of surface water and climate monitoring data loggers.

Management implications

- At Toolibin Lake, understanding the post-February 2017 lake water level recession and subsequent winter inflows will enable the competing processes of evaporation and transpiration to be quantified.
- The conceptual model of the Toolibin Lake salt balance will provide critical spatio-temporal information to inform revegetation efforts and development of an optimised groundwater pumping program and will form an integrated platform for assessing the needs for current and future engineering works.
- Revised rationalisation of monitoring programs creates further efficiencies in the delivery of high quality data to inform research and ongoing management.

Future directions

- Develop a spatio-temporal conceptual model of deep-rooted vegetation resilience on Toolibin Lake and assess hydrological critical criteria that influence the success and decline of different plant species.
- Update conceptual and numerical hydrological models to include and interpret data collected from the 2017-2018 Toolibin Lake inundation event.
- Undertake sampling of groundwater beneath Toolibin Lake (environmental tracers and borehole geophysics) to assess flushing of aquifer solutes following the 2017-2018 inundation event.
- Complete internal report, journal article and a Science Information Sheet on Toolibin Lake hydrology.



Taxonomy, zoogeography and conservation status of aquatic invertebrates

SP 2014-025

A Pinder, M Pennifold, 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 paper describing a new species of *Boeckella* copepod from a claypan on Matuwa was published.
- A book chapter on Australian and New Zealand aquatic oligochaetes was completed.
- An annotated checklist of Western Australian rotifers was commenced.
- Scanning electron micrographs of two undescribed species were taken with a view to describing them.
- A rapid assessment of rare and restricted aquatic invertebrates of south-west Western Australia was undertaken, identifying about 50 potential Priority Species. These mostly require some further assessment but 10 have been assessed in more detail and proposed for listing as Priority Fauna.

Management implications

- A number of aquatic invertebrates have been added to the list of Priority Fauna and these will need to be taken into consideration during environmental impact assessments.
- The description of new species and the production of taxonomic tools, such as the book chapter on aquatic oligochaetes, 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, L Bourke

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

- Undertook scanning electron microscopy work to resolve and quantify fine scale (nanometre scale) mineralogy to assess geochemical zonation and acid stores.
- Commenced development of a 3D conceptual model that integrates hydrogeophysical and hydrogeochemical data and interpretations.

Management implications

- The absence of bacteria that breakdown vegetation to form peat in disturbed peat wetlands confirms that these systems are under stress. The cause of the stress and likelihood of their recovery are factors that require consideration in management of peat wetlands.
- All peat wetlands have the potential to become acidic but they can be effectively managed if substrate geochemical gradients and discrete zones releasing acids are mapped and understood.
- Identifying the discrete zones within peat wetlands prone to acidification and drying allows management plans and actions to be developed and prioritised.

Future directions

- Complete work on the three dimensional understanding of the hydrogeology, water, salt and acid stores in order to understand spatial variability and identify wetlands where interventions are likely to be effective and the risk of peat fires reduced.
- Write a report, journal article and 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 (climate change, fire) to these systems.

Restoring natural riparian vegetation systems along the Warren and Donnelly Rivers

SP 2013-004

M Byrne, T Hopley, T Macfarlane, C Yates

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 River and Donnelly Rivers.
- Test adaptation to climate through experimental plantings under operational conditions of establishment.

Progress

- A manuscript detailing the patterns of genetic structure and landscape variables that explain genetic differentiation across the catchment for *Astartea leptophylla* and *Callistachys lanceolata* has been accepted for publication.
- A manuscript detailing the results from association analysis outlining the number and scale of signals of adaptation for *A. leptophylla* and *C. lanceolata* has been submitted and is currently under review.
- A manuscript detailing the genetic structure and signals of adaptation that were found in *Taxandria linearifolia* is currently being written.

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. Development of a strategic revegetation program for the riparian areas of the Warren and Donnelly catchments has provided an integrated approach to habitat restoration and improved the knowledge and capacity of restoration practitioners and land managers.

Future directions

- Finalise manuscript on signals of adaptation for *A. leptophylla* and *C. lanceolata*.
- Complete and submit manuscript on *T. linearifolia* genetic structure and signals of adaptation.
- Write final manuscript exploring the implications for restoration.

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 on three standardised transects was maintained with three repeat surveys per transect in spring 2017 and autumn 2018.
- Ngwayir (western ringtail possum) populations in the greater Kingston area remain extremely low having declined to almost undetectable levels between 2001 and 2012. Spotlight detections increased slightly 2012-2014, but have remained relatively stable 2015-2018 at less than 5% of the level typical of the pre-2000 era.
- Results and insights from this study were included in the book chapter 'Insights from multi-species mammal monitoring programs in the Upper Warren, Western Australia' published in the book *Monitoring Threatened Species and Ecological Communities.*

Management implications

- The declines 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

N Gibson, G Keighery, M Lyons, S van Leeuwen, A Markey, B Bayliss, M Langley, R Coppen

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:

- AusPlots Rangeland survey sites as a baseline for long-term surveillance monitoring in collaboration with the Terrestrial Ecosystems Research Network (TERN).
- Floristic survey and mapping of the halophyte-dominated communities of the Fortescue Marsh.
- Capture of vegetation mapping data for the central Pilbara to inform natural resource management and land use planning.
- Black spot flora survey of the Colville 1:100,000 map sheet.
- Resurvey threatened claypan communities on the Swan Coastal Plain to document change.
- Floristic survey of the mound springs and surrounding vegetation communities of Mandora Marsh / Waylarta in collaboration with the West Kimberley District.
- Floristic survey of the coastal wetlands of the Jurien area.

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

- Floristic communities have been described for the Fortescue Marsh, these halophyte-dominated communities have been mapped for the Marsh Land System and report completed.
- Flora survey of Mandora Marsh / Walyarta has been finalised and a report prepared.
- Jurien coastal wetlands survey has been completed, and preparation of a scientific paper is underway.
- Vegetation map reconciliation continued with the digital capture of over 400,000 ha of mapping in the central Hamersley Range between Newman and Weelumurra.
- Plant identification from AusPlots sites in Western Australia were completed and acquittal reports compiled..
- Manuscript submitted on temporal changes in critically threatened claypan communities on Swan Coastal Plain in collaboration with Swan Region.
- Paper accepted outlining availability of plot data in Western Australia in response to paper by Gellie *et al*. 2018.

Management implications

- The survey of the Colville area has increased the flora known from this isolated part of Western Australia and will assist in land use planning and impact assessments for future resource development.
- Analysis of the Fortescue valley claypan data will provide information on the temporal variation in these threatened communities, as well as assist in developing methods to assess ecosystem health.
- Surveys of Mandora Marsh / Walyarta and the Fortescue Marsh will provide information for draft management plans for existing and proposed reserves in the southern Kimberley and Pilbara.
- The Jurien coastal survey will provide information on wetland flora values to assist in land use planning and impact assessments for mining and water resource developments.
- The digital capture and reconciliation of vegetation maps in the Pilbara will inform environmental impact assessment processes associated with native vegetation clearing permits and major resource development proposals. This will also provide information for fire management planning, particularly the development of burning prescriptions for Karijini National Park and the Fortescue Marsh.
- Changes over the past 20 years in the flora of claypan communities on the Swan Coastal Plain indicates that South African geophytes and perennial grasses pose the most serious threat to these communities.

Future directions

- Manuscript on analysis of the Fortescue Valley claypan dataset will be completed.
- Manuscript on the Jurien coastal wetlands survey will be completed.

Western Australian terrestrial fauna surveys

SP 2011-021

M Cowan, L Gibson, A Burbidge

Context

The department, with the assistance of the Western Australian Museum, has a long-standing commitment to undertaking regional biogeographic surveys of the State. These surveys have underpinned the selection of areas for the conservation reserve system, provided information to determine the conservation status of species and filled significant gaps in biodiversity knowledge. While large scale surveys provide analyses of biodiversity patterning for regional-scale conservation planning, sites are usually too sparse and often lack detail for decision making at finer scales. The more localised surveys undertaken will fill spatial and/or habitat gaps in the larger regional surveys, extend geographic coverage, assist in resolving taxonomic issues, increase ecological understanding, provide information on fine-scale biodiversity patterns and complement regional surveys.

Aims

- Provide understanding of landscape-scale terrestrial fauna biodiversity and patterning to inform conservation planning and as a baseline for future monitoring.
- Collect, manage and interpret data on the distribution, ecological tolerances and conservation status of terrestrial fauna species and communities.

Progress

- Completed a review of the usage and risk posed by abandoned mine shafts to fauna in the Goldfields for the Department of Mines, Industry Regulation and Safety.

Management implications

- These fauna surveys contribute to improved species distributional and ecological understanding, prioritisation of conservation actions by local managers, and/or the assessment of potential environmental impacts of land use development proposals. Individual survey projects assist regional conservation and land managers to understand local biodiversity patterning and its underlying drivers, and permit the use of this information to assess environmental impacts, prioritise conservation actions, set biodiversity management targets and establish baselines for monitoring and detecting change. The combination of surveys enables improved understanding of species distributions and habitat requirements at a State level, thus contributing to bioregional analyses, assessment of the design of the conservation estate, reviews of species conservation status and analyses of the relationships between species and broad-scale gradients and threats such as climate change.

Future directions

- Undertake Black Spot Map Sheet and other biological survey when and as opportunities arise.
- Collate data from the Edgar Range, Nimalarragun and Kurrara Kurrara Surveys and upload to NatureMap.

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

SP 2011-020

L Mccaw, G Liddelow, 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 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 predominantly of 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

- A collaboration with The University of Western Australia has been developed to use data from a long-term thinning experiment in 100 year old regrowth jarrah forest at Inglehope block near Dwellingup to verify predictions from a process-based forest growth simulator.
- Analysis of the latest Inglehope data has commenced with the aim of fitting Weibull growth curves to examine the relationship between forest stand increment and stand density.
- Second thinning commenced at an experimental site in 45 year-old regrowth karri forest at Warren block near Pemberton.

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

- Analyse and report on trends in jarrah tree and stand growth at Inglehope, with a focus on links between climate and growth.
- Complete the second thinning at Warren block, and re-establish site infrastructure required for long-term monitoring of karri stand growth and health.

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 10 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

- A study investigating effects of understorey removal by fire on pheromone trap catch was continued in summer 2018. A manuscript was submitted and is in revision.
- Jarrah leafminer outbreak in Yelverton Nature Reserve was investigated in October 2017 and a departmental report on the outbreak and other insect damage in the area was prepared and disseminated to relevant staff and affected regional and district offices.
- A report was prepared and disseminated describing common defoliator damage symptoms on *Eucalyptus* leaves in south-west Western Australia.
- A paper is in preparation dealing with a historical *Cardiaspina jerramungae* outbreak and the recurrence of rainfall conditions coincident with outbreak in the 1980s in the Great Southern.

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.
- Interference with pheromone based mate finding by vegetation has implications for moth species richness at landscape scales because pheromone based mate finding is common in moths (including other *Eucalyptus* defoliators). Understanding drivers of moth richness may allow spatial predictions of moth species richness and enhance understanding of effects of global change on moth biodiversity.

Future directions

- Undertake pheromone trapping at long-term monitoring sites to validate models of population outbreak driven by climatic factors.

Western Australian wetland fauna surveys

SP 2011-018

A Pinder, K Quinlan, R Coppen, 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 a poster and a Science Information Sheet for the survey of biodiversity at Fortescue Valley wetlands and presented this work at the 2018 Western Australia Wetland Management Conference.
- Surveyed northern Wheatbelt wetlands for *Parartemia* brine shrimp to assist with determining the conservation status of *P. extracta*.
- Surveyed aquatic invertebrates and flora at springs on the west and east Kimberley coast. Identifications of flora and aquatic macroinvertebrates completed.
- Surveyed aquatic invertebrates and flora at Nimalarragan wetland at the inland extent of Willie Creek. Progressed sample processing and identification.
- Paper published in *Ecography* on patterns and drivers of aquatic invertebrate diversity across an arid biome.
- Sampled aquatic invertebrates at the Brixton Street wetlands.
- Undertook a genetic barcoding project to enable more consistent identification of aquatic invertebrates and to contribute data to the Aquatic Invertebrates of Australia project on the Barcoding of Life Database.

Management implications

- In the Cervantes to Coolimba wetland system, the survey of wetland flora will assist with assessment of proposals to expand gypsum mining and determining the ecological water requirements of groundwater dependent ecosystems.
- In the Fortescue Valley, the survey of wetland biota will inform efficient off-reserve wetland conservation planning in an important area for wetland biodiversity in the Pilbara.
- *Parartemia extracta* is likely to be restricted to the Cervantes to Coolimba salt lakes and its conservation status needs to be assessed.
- Priority Ecological Communities (Assemblages of the wetlands associated with the organic mound springs on the tidal mudflats of the Victoria-Bonaparte Bioregion) on Carlton Hill Station are threatened by changed hydrology as a result of planned irrigated agriculture. The survey conducted in August 2017 will more completely document these springs and their biota and help understand their vulnerability to altered hydrology.

Future directions

- Publish a paper on invertebrate diversity in vegetated claypans of south-west Western Australia.
- Complete a paper on Cervantes to Coolimba region wetland flora.
- Write reports on the Kimberley springs and Nimalarragan wetland surveys.
- Write a paper on biodiversity patterning across Kimberley springs.
- Survey additional wetlands (including the Type locality) in the northern Wheatbelt for *P. extracta*.
- Process samples of aquatic invertebrates collected from Goldfields wetlands in 2017 and survey additional Goldfields Region wetlands depending on rainfall.
- Further assess the conservation status of south-western Australian aquatic invertebrates.

Protecting the safe havens: will granite outcrop environments serve as refuges for flora threatened by climate change?

SP 2011-011

C Yates, M Byrne

Context

Many plant and animal species have survived previous climate change by contracting to dispersed refugia where local climate conditions ameliorate regional changes. Such refugia will likely contribute to the persistence of biodiversity under projected climate change. In south-west Western Australia, the old, highly weathered and flat landscape offers little scope for the biota to migrate to altitudinal refugia during climate change. However, the many granite outcrops (GOs) scattered across the region provide a suite of habitats and conditions not found in the wider landscape and these may ameliorate the impacts of regional climate change.

Aims

- Investigate the potential of GOs and their associated environments to act as refugia in the face of anthropogenic climate change across south-west Western Australia.
- Determine whether topographic and microhabitat features of GOs designate them as refugia.
- Use phylogeographic patterns to determine whether GOs have acted as refugia in the past and are important reservoirs of genetic diversity.
- Determine whether particular environments at the base of GOs are more productive, and whether individual plants in these environments are under less stress than those in the intervening matrix.
- Determine whether plant communities of GOs are more resilient to anthropogenic climate change disturbances than the communities of the surrounding landscape matrix.

Progress

- A paper has been submitted on patterns of floristic composition in GO plant communities and their relationships with climate, topographic and microhabitat features on outcrops.

Management implications

- Identification of areas that can act as refugia under projected climate change enables adaptation and conservation activities to be focused where they will provide greatest benefit in facilitating species persistence and continued ecosystem function.

Future directions

- Publish papers on patterns of floristic composition in GO plant communities and their implications for conservation.

Identification of seed collection zones for rehabilitation

SP 2006-008

M Byrne, D Coates, 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

- A paper has been published in *Biological Journal of The Linnean Society* on the analysis of nuclear genetic variation and cpDNA variation in marri (*Corymbia calophylla*). There was little genetic structure across the species range consistent with a strong influence of pollen dispersal in maintaining connectivity among populations, but some evidence of effects of current environment (aridity). Phylogeographic analysis revealed population persistence in mesic habitats but unexpected episodic range expansion from the early Pleistocene, probably in association with progressive drying and major climatic changes.
- A paper is in preparation on the genetic relationships among *C. calophylla*, *C. haematoxylon* and *C. ficifolia*, that show distinct genetic separation in the nuclear genome and shared cpDNA haplotypes, consistent with shared evolutionary history.
- Analysis of microsatellite variation and cpDNA variation in 28 populations of *Banksia sessilis* revealed two major genetic clades, one on the Darling Range and Plateau, and another on coastal limestone that exhibited both 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. A paper is in preparation.

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 phylogeographic patterns and genetic structure, and seed sourcing strategies for *B. sessilis*.

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

SP 2006-003

L Mccaw, J Farr, G Liddelow, V Tunsell, B Ward, A Wills, B Huntley

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

- Work continued on preparation of scientific papers reporting the second round of monitoring completed between 2007 and 2012. A manuscript synthesising changes in species assemblages between the first and second rounds of monitoring in relation to climatic factors, changes in forest structure and improved sampling methods was revised in preparation for submission.
- Seven monitoring grids in Wellington District burnt by the large Lower Hotham bushfire in February 2015 were re-sampled. Samples from invertebrate pitfall and light trapping at burnt sites in spring 2016 and autumn 2017 were sorted and classified. Monthly inspections to identify vascular plant species in flower were continued into the third year after fire, revealing a number of species not recorded previously at these grids, including a significant range extension and a potential new species.
- Information about the composition and abundance of weeds at 48 monitoring grids was collated for inclusion in the Forest Management Plan mid-term performance report.
- Trends in vegetation cover at each monitoring grid were used to verify satellite imagery for reporting on forest condition for the Forest Management Plan mid-term performance report.
- Post-burn assessments were undertaken on six grids burnt by prescribed fire. A manuscript presenting models for woody fuel consumption is being prepared.

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. Sixty seven monitoring grids have now been established, with 50 of these sampled at least twice.
- 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

- Finalise analysis of data from the 10-year monitoring period (2002-2012) and publish results.

- Review monitoring protocols and incorporate new techniques where these will improve efficiency and quality of data collected.
- Prepare manuscripts reporting on consumption of coarse woody debris and the initial response of vascular plants and invertebrates following the 2015 Lower Hotham bushfire.

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

SP 2000-003

J Kinal, G Liddelow

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 Swan Region.
- Preparations are underway for a second thinning in Yarragil 4L catchment, 35 years after the previous thinning, to inform silviculture for water production and ecosystem health. This included installation of a new stainless steel V-notch plate to replace the existing corroded plate.
- Tree growth and stand density were measured to determine long-term growth response to thinning at Yarragil 4L.
- A paper reviewing the long-term hydrological response to thinning in Yarragil 4L is being revised following peer review.
- Groundwater bores were re-measured in spring 2017 and autumn 2018 at experimental catchments in the Warren Region including Crowea, Iffley, Poole, March Rd and April Rd. More than 80 bores were measured, with 45 still being in contact with groundwater.

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.

Future directions

- Continue monitoring of groundwater levels, streamflow and water quality in the Yarragil catchment.

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

SP 1998-007

M Byrne, D Coates, 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 minesites in the Pilbara and the Midwest.

Progress

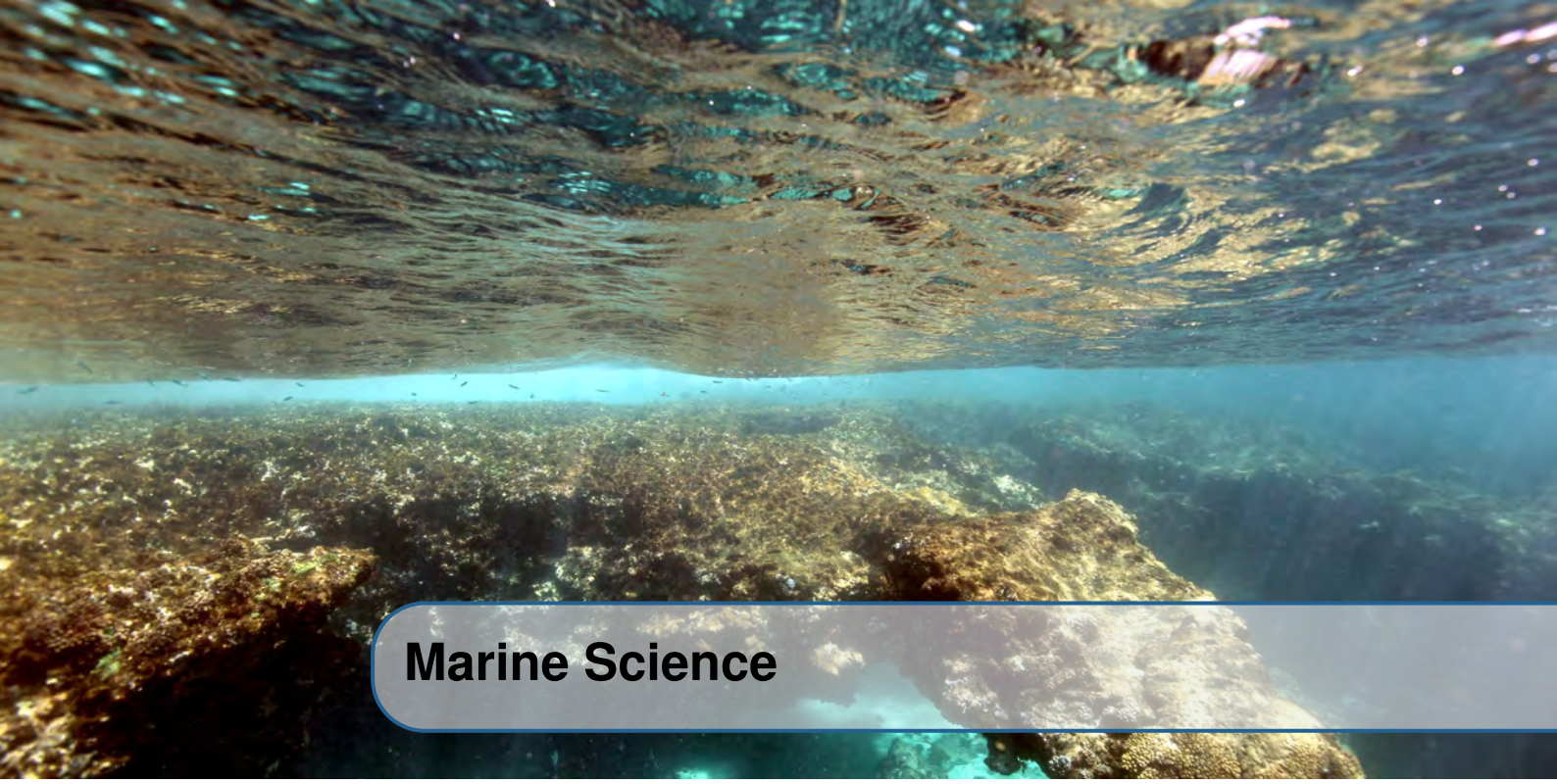
- Data analysis for both nuclear and cpDNA markers is complete for eight species in the Pilbara for the identification of seed collection zones, *Petalostylis labicheoides*, *Indigofera monophylla*, *Senna glutinosa*, *Corymbia hamersleyana*, *Acacia pruinocarpa*, *A. hilliana*, *A. spondylophylla* and *Mirbelia viminalis*. Papers on these studies are in preparation.
- A synthesis paper on modelling seed collection and restoration establishment scenarios for *Grevillea paradoxa*, *Melaleuca nematophylla, Mirbelia* sp. *bursarioides* and *G. globosa* has been accepted for publication in *Australian Journal of Botany.*

Management implications

- Pilbara seed collection zones - The high levels of genetic diversity and low levels of differentiation within *E. leucophloia* and *A. ancistrocarpa* imply that, for these species, seed resources for land rehabilitation and mine-site revegetation programs can be selected from a wide distributional range within the Pilbara. However, phylogeographic analysis of *E. leucophloia* has identified the Hamersley Range as a historical refugium, so seed collections for rehabilitation of mine sites using this species should be targeted within the Hamersley Range to maximise the diversity of these sites. In contrast, the low diversity and high population differentiation in *A. atkinsiana* indicates that more restricted seed collection zones should be observed.
- *Aluta quadrata* -The significant genetic structure in *A. quadrata* indicates three conservation or management units: Western Range, Pirraburdoo and Howie's Hole. Given the genetic differences, restricted distribution and size of the populations, a precautionary approach should be taken to seed collections. Establishment of restoration populations within gene flow distance of existing populations should be done with seed from the location of that population. However, mixing seed collections from the three locations for establishment of restoration sites located distant to existing populations would be a means of maximising genetic diversity for future conservation.
- Midwest seed collection zones - Genetic analysis of four species has provided a basis for identification of seed collection zones for land rehabilitation and mine-site revegetation programs, with species wide collections for *M. nematophylla* (except for the divergent Murchison River gorge), *G. globosa* and *Mirbelia*sp. *bursarioides*, while three regional seed collection zones were identified for the bird-pollinated *G. paradoxa* that showed limited pollen dispersal.

Future directions

- Four papers will be written, reporting genetic results for eight Pilbara species with recommendations for seed collection zones.



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.

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

SP 2015-015

M Moustaka, M Mohring, T Holmes, S Wilson, A Kendrick

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 manuscript on historical coral cover and associated environmental drivers in waters surrounding the Dampier Archipelago is in preparation for submission to the journal *Diversity*.

Management implications

- This project will produce baseline data on various key ecological assets and the pressures acting on them, as well as several recurrent surveys to detect trends in key asset condition. An established monitoring program will inform managers of trends in asset condition to facilitate long-term adaptive management for the proposed reserves, and promote environmental understanding for a range of stakeholders and the community.
- New marine monitoring indicators and methods for key ecological assets and habitats that are largely novel to northern Western Australia, will provide a sound basis for management of the proposed marine reserves planned for the Dampier Archipelago.

Future directions

- Second monitoring surveys of mangrove, seagrass and macroalgae communities will be completed. Initial surveys of benthic macroinvertebrates will also be completed on this trip.
- Coral settlement tiles will be deployed and collected in 2019 in collaboration with CSIRO.
- A third and final monitoring survey of coral and fish communities will be completed.

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

SP 2014-021

K Waples, H Raudino, C Douglas, R Douglas

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

- Six boat-based dolphin surveys have now been undertaken in coastal waters around Onslow. Survey data were used to estimate the density and abundance of bottlenose and humpback dolphins using a POPAN modelling approach and this work has now been published in *Regional Studies in Marine Science*.

- A third aerial survey was conducted in coastal waters of the Pilbara extending offshore to the 20 metre depth contour (approximately 40km offshore), including the Montebello Islands (approx. 60km from the mainland). Survey data is being used to produce estimates of dolphin abundance and density for the area. A collaborative project with Murdoch University is investigating the surface availability of humpback dolphins that is needed to produce a correction factor that can be applied to improve the accuracy and confidence in abundance estimates of this species. Data collection and processing phase of this project is now complete.
- Cameras were used in the aerial survey to collect high quality archived images of a sufficient resolution that can be used to differentiate the species being surveyed. These results support the move towards unmanned aircraft to undertake surveys of multiple marine mammals species in future.
- Survey data have been collated with environmental factors in MAXENT models of species distribution. These data used for the MAXENT models will be used to populate a spatial risk assessment model (INVEST) with a number of other relevant layers.
- A second boat-based survey of Exmouth Gulf was undertaken in an attempt to identify critical habitat for snubfin dolphins and determine population viability and size, but the species was not detected during the survey. Data on dugong, and humpback and bottlenose dolphins were collected and this will contribute to knowledge of the density and habitat use and a spatial risk assessment of these species in the Gulf.
- The results of a boat-based survey conducted at the Montebello Islands were published in *Marine Biodiversity Records.*
- Satellite tag design and deployment on humpback dolphins was investigated as an option of recording home range and movements but suitable tags that are small enough and can be deployed remotely have not yet been identified.
- The applicability and success of using drones to sample blow for DNA from dolphins was explored as a potential alternative to biopsy darting.

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

- The established vessel survey methodology and design will be undertaken for a fifth and final year with a focus on the Dampier Archipelago area in partnership with the Pluto offset research and monitoring program.
- Aerial survey data will be analysed to produce an estimate of abundance and prepared for publication.
- Species distribution models will be combined with other spatial data layers to assess risk to the target species (dugong, humpback and bottlenose dolphins) across the Pilbara region.

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 insufficent 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 the Pilbara region of Western Australia,

there has been little Western Australian 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. This project will assess dolphin distribution across the Kimberley region between 2004-2012.

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

- Information obtained on abundance of snubfin dolphins was presented at the 2017 Biennial Conference on the Biology of Marine Mammals in Halifax, Canada.
- A manuscript on snubfin dolphin abundance contrasting distance sampling and mark-recapture survey techniques in Roebuck Bay is undergoing final statistical analysis and revision prior to submission to a peer-reviewed journal. Mark-recapture analyses are complete, while distance sampling analyses are being undertaken by an external collaborator.
- Utilisation of recent data (2013-2015) to investigate long-term site fidelity and home range of individual snubfin dolphins in Roebuck Bay is progressing.
- The first edition of the Yawuru Nagulagun Roebuck Bay snubfin dolphin photo identification was produced from a collation of images from multiple custodians between 2007-2017. The project was a collaboration between Environs Kimberley, Yawuru, Marine Science Program, Dolphin Watch, and regional Parks and Wildlife Service staff.
- The Dolphin Watch app, already used by the department in the south-west, has been expanded to include tropical dolphin species in northern Australia so that it may be used by managers and the community to record dolphin sightings in key areas such as the proposed Yawuru Nagulagun / Roebuck Bay Marine Park. An outreach project was held to train stakeholders in the use of the app with the view of better understanding the habitat use of snubfin dolphins in the area and life history information at the individual level from dorsal fin images (where photo quality allows).

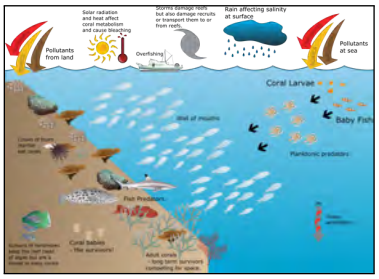
Management implications

- 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 proposed 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 modeling 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 plans and reserve management plans.
- The Dolphin Watch app and Finbook photo-identification guide will support ongoing monitoring of the snubfin dolphin population and will be used towards fulfillment of KPIs on maintaining abundance and

diversity of these dolphin species in the Yawuru Nagulagun / Roebuck Bay Marine Park.

Future directions

- Submission of a manuscript on a population estimate of snubfin dolphins in Roebuck Bay.
- Revision of a manuscript on cross-cultural knowledge of the distribution of snubfin dolphins in the Kimberley to include species distribution modelling.
- Completion of the Dolphin Watch app and Finbook photo-identification guide.



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, M Byrne, R Douglas, R Binks, 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

- Coral recruitment settlement tiles were deployed and collected in the Onslow region for the fifth and final year of the temporal study of recruitment processes.
- A fifth *in situ* assessment of recruit corals on Onslow region reefs was undertaken using quadrats with underwater visual census and digital photographs.
- Development of single-nucleotide polymorphisms (SNPs) for the coral, *Turbinaria reniformis*, were developed. Unfortunately the SNPs for the other coral species, *Cyphastrea microphthalma*, were unsuccessful in the development stage.
- Manuscripts are being prepared on analyses of seagrass, coral and fish data.
- A manuscript on mangrove population genomics and connectivity has been accepted in the journal *Diversity and Distribution*.
- A manuscript on the effects of sediment on fish was published in the journal *Coral Reefs*.
- A manuscript on seagrass clonality was published in the journal *Frontiers of Plant Science*.
- A manuscript on dredging impacts on fishes was published in *Conservation Letters*.
- Findings of this study were presented at conferences of the Australian Society of Fish Biology and the Australian Coral Reef Society.

Management implications

- The project will improve our understanding of how well populations of marine species are linked, providing an indication on how fast they are likely to recover following natural and anthropogenic disturbances, with a focus on key habitat forming species that support important ecological processes.
- Understanding the extent of connectivity for different taxa will inform marine planners about how reserves and management zones can be configured to best facilitate propagule transfer among meta populations, therefore improving recovery potential after disturbance.
- Improved temporal understanding of the impact of natural and human disturbance in the Pilbara, as well as the demography and recovery potential of coral communities, will allow resource managers and industry to understand the resilience of the system, and allow for better spatial and temporal planning of developments and general use management zoning.

Future directions

- Analyses of genetic data for coral species will be completed and manuscripts for all taxa will be prepared.
- A synthesis of the genetic findings for all taxa will be prepared.
- The fifth year of data on coral settlement will be analysed and coral settlement tiles will be redeployed to determine settlement differentials across the period of spawning.
- Analysis and preparation of a manuscript on coral recovery potential in the Onslow region.

The influence of macroalgal fields on coral reef fish

SP 2013-006

S Wilson, T Holmes

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 ~2,000 ha. 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

- Climatic forcing, measured as swings in the Southern Oscillation Index (SOI), were correlated to seasonal abundance of juvenile fish. The relationship was especially strong for fish that recruit into macroalgal habitats, the structure of these habitats also being seasonally influenced by the SOI. This work was published in *Ecology and Evolution.*
- The importance of macroalgal fields as fish habitat were presented as a keynote lecture at the Australian Coral Reef Society conference in Exmouth, as a guest lecture at Lancaster University (UK) and as presen-

tations at the Indo-Pacific Fish Conference in Tahiti and Australian Society of Fish Biology Conference in Albany.

Management implications

- Marine conservation managers and planners will have a greater understanding of the ecological and social importance of macroalgal habitats in Western Auslralia's tropical north. This includes the ecological importance of macroalgal fields as habitat for fishes and their role in supporting key processes such as recruitment. This knowledge will also improve the capacity to predict future abundances of adult fishes, particularly those threatened by changes to habitat, climate and fishing pressure, and will help to maintain important social values like recreational fishing.
- An improved understanding of the distribution of macroalgal fields in tropical Western Australia will improve predictions of the ecological significance of algal biomass when planning and managing marine reserves.
- This study of macroalgal communities will provide baseline data for future long-term monitoring of the condition of macroalgal communities in marine reserves.
- Understanding how climatic processes effect both the supply of juveniles and quality of nursery habitat improves our understanding of temporal fluctuations in fish abundance and ability to predict future populations.

Future directions

- Data on the abundance of fish in macroalgal fields from tropical locations around the globe is being collated and a meta-analysis is being prepared for a review paper.
- Undertake data analyses to understand links between juvenile and adult fish, and assess the relative importance of juvenile abundance and suitable habitat.

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 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

- Flatback turtles were tracked from nesting beaches at Thevenard and Delambre islands with the results helping to identify inter-nesting habitat, migration routes and new foraging areas.
- Turtle foraging areas have been identified in the Pilbara and Kimberley with many foraging areas supporting turtles originating from different rookeries. A major result in the past year was the identification of a flatback turtle foraging area near Broome and the subsequent tracking of individuals from this area.
- Tracking fieldwork was undertaken in partnership with regional Parks and Wildlife Service staff and traditional owners where possible.
- Tracked turtles were often named by local communities or schools and real time movement data were made available to the public through the website www.seaturtle.org to promote engagement and educational opportunities.

Management implications

- Identifying nesting habitat, inter-nesting habitat, migration routes and foraging areas.
- The identification of new key habitats used by the Northwest Shelf flatback turtle stock includes foraging areas in the southern Pilbara, inshore inter-nesting areas near Onslow and the confirmation of foraging areas in the north Kimberley.
- The information collected will assist Parks and Wildlife Service marine park staff and traditional owners identify important areas, assess current pressures and implement management, as required.
- The information has recently been used for marine park planning in the Kimberley and development assessment advice.
- Tracking the movements of large marine animals provides an opportunity to engage the interests of people from all walks of life. Partnerships with local departmental staff, traditional owners and traditional owner ranger teams enhances education throughout local communities and schools while accessible data and media coverage increased engagement with the general public.

Future directions

- Continue efforts to track turtles from within foraging areas.
- Undertake research into improving how transmitters are attached to flatback turtles.

Marine Monitoring Program

SP 2012-008

T Holmes, G Shedrawi, K Bancroft, S Strydom, E D'Cruz, B French, W Robbins, M Mohring, M Moustaka, M Rule, A Kendrick, K Murray, S Wilson

Context

A state-wide system of marine protected areas is being established in Western Australia as part of Australia's National Representative System of Marine Protected Areas. Long-term monitoring of the condition of environmental assets and social values is recognised 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 being developed and implemented to increase the efficiency and effectiveness of marine reserve and threatened marine fauna conservation and management.

Aims

- Develop and implement a long-term monitoring program for Western Australia's marine parks and reserves and threatened and specially protected marine fauna to facilitate and promote management effectiveness in the protection and conservation of marine biodiversity and related social values.

Progress

- Updated monitoring data was collected for fish, coral, seagrass, macroalgae, mangroves, macro-invertebrates, little penguins, Australian sea lions and water quality during fieldwork conducted across 11 marine reserves from Walpole and Nornalup Inlets Marine Park in the south to North Kimberley Marine Park in the north.
- Monitoring advice was provided to Parks and Wildlife Service marine park coordinators on the condition of biodiversity assets and the significance of pressures acting on them to inform adaptive management strategies and marine reserve audit processes.
- Marine monitoring data sets continued to be added to the CKAN data catalogue, and have been tested for use with the *BioSys* database.
- The first document in the new Marine Science Program monitoring report series was published as *Ecological monitoring in the Ningaloo marine reserves 2017*. Subsequent reports for the Shark Bay marine reserves, Jurien Bay Marine Park, Shoalwater Islands Marine Park and Montebello/Barrow Islands marine conservation reserves are currently in preparation.
- Staff attended and presented monitoring work at national/international conferences at Exmouth (Australian Coral Reef Society conference), Sydney (Australian Mangrove and Saltmarsh Network conference) and Singapore (World Seagrass Conference).
- Staff have been invited to attend and become active participants in a number of national workshops and working groups, including the National BRUV Synthesis working group, National MPA Science/Management Network forum, National Marine Parks MER workshop, and Essential Environmental Measures working groups.
- Monitoring staff are collaborating on two ARC Linkage projects relating to temperate rocky reefs (led by the University of Tasmania) and coral biodiversity in the Kimberley (led by Curtin University)
- Training continued for departmental staff, interns and volunteers on laboratory and field protocols for collecting and analysing monitoring data for coral, fish, seagrass, mangroves and little penguins.
- Four scientific papers incorporating departmental monitoring data were published in the journals *Ecological Indicators*, *Ecology and Evolution*, *Diversity and Distributions*, and *Nature Climate Change*. These papers were on the effects of climatic forcing and larval dispersal capabilities on the replenishment of tropical corals, the role of disturbance events and environmental conditions on the structure of coral communities throughout the south-eastern Indian Ocean, the loss of seagrass in Shark Bay as a result of a marine heat wave, and a conversion technique for comparing fish community data sets collected using differing methods.
- Work continues on a publication that describes the aims and structure of the department's marine monitoring program.

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 assets, the pressures acting on those assets and the management response. 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 assets based on rigorous scientific evidence.

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 assets.
- Continue the design and implementation of ecological asset monitoring across the marine reserve system, including at recently created reserves in Western Australia's Kimberley region.
- Continue to provide marine park managers with evidence-based knowledge of the condition of key ecological assets and the pressures acting on them to inform and assist the delivery of adaptive management.
- Continue to provide the scientific knowledge required for the department's 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 the NWSFTCP Strategic Plan.

Progress

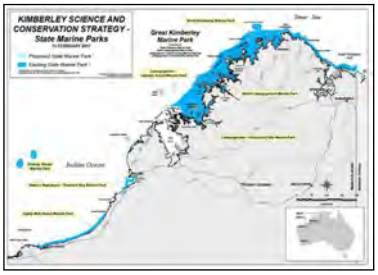
- The NWSFTCP Strategic Conservation Plan has been completed and management actions are underway to meet the milestones of the plan.
- Major milestones this year included improving financial coding to allow for better interrogation of expenditure; completion of the WAMSI Turtle Project that included shared objectives with this plan; identification of flatback foraging areas; transfer of the Delambre nesting monitoring program from Rio Tinto to the department; and increased traditional owner engagement and employment.

Management implications

- The NWSFTCP Strategic Conservation Plan maps out the foundations of the program to establish a robust program of works within a strategic long-term framework. The NWSFTCP provides an opportunity to fill key gaps in knowledge, establish long-term monitoring, and deliver management outcomes for flatback turtles whilst more generally providing a framework for conservation and management of all marine turtles in Western Australia.
- This project provides information and advice to marine park planners, healthy country plan custodians, managers of Indigenous land and sea Country and regulatory authorities responsible for development assessments.

Future directions

- In the next year, major deliverables for the program will include increased efforts to identify and understand flatback turtle foraging areas; continued fox mitigation at major rookeries; and continued efforts to jointly build Indigenous partnerships, engagement and employment opportunities.



WAMSI 2: Kimberley Marine Research Program

CF 2011-117

K Waples, S Field

Context

The Kimberley Marine Research Program (KMRP) is undertaking a program of marine research to support the management of the Great Kimberley Marine Park (which will include state marine parks at Camden Sound, Horizontal Falls, North Kimberley, Roebuck Bay and Eighty Mile Beach) and the coastal waters outside of these proposed marine parks. The KMRP was developed and is being 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 was developed to address priority research and information needs to support the management of ecological and social values in the Kimberley region through joint management of the Kimberley marine park network. 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 will be undertaken between 2012 and 2017 and involve up to 80 scientists from eight research or management institutions in Western Australia working collaboratively on 25 research projects. Aboriginal involvement is a key component to the success of the research program and all projects are engaging with Aboriginal people and developing partnerships with the relevant traditional owners to include their participation and to ensure the research outcomes benefit local communities.

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

- Field research has been completed for all 25 projects. Fourteen of these projects have included participation by traditional owners in field work.
- Final reports have been received for 24 of the 25 projects, with 21 approved and three pending minor editing.
- Lunchtime seminars have been held for all projects to share key findings with departmental staff and other stakeholders
- A final synthesis symposium showcasing science in the KMRP was held.
- The working group comprising representatives from seven indigenous communities has received additional support to continue to work together on sharing information and techniques for healthy country planning and management.
- The Knowledge Uptake Strategy is being implemented through a range of activities, including media engagement, online project profiles and presentations.

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

- Ensure that key research findings are shared with stakeholders in a format that allows for direct discussion and feedback on management needs, including products and tools that will support ongoing collaboration and management.
- Complete the KMRP Node final report as a synthesis of the research program that will provide a regional perspective on marine biodiversity, ecosystem function and the pressures on these values which can be moderated through management.
- Complete remaining research project priorities for the Kimberley and share with key management staff.
- Work with other departmental staff to identify and progress the development of management tools and products.

WAMSI 1 Node 3: science administration, coordination and integration

CF 2011-116

K Waples, A Kendrick

Context

In 2005, the State Government allocated $5 million to undertake research that would underpin management at Ningaloo Marine Park. A research plan was developed to address key strategies in the Ningaloo Marine Park Management Plan. In 2007, a joint research body, the Western Australian Marine Science Institution (WAMSI) was formed. The department was the leader of Node 3 of WAMSI, which addressed research in marine biodiversity and conservation. At the same time as the development of WAMSI, CSIRO Wealth from Oceans National Research Flagship program established the Ningaloo Collaboration Cluster (the Cluster) to address the integration of knowledge of reef use, biodiversity and socio-economics into a Management Strategy Evaluation (MSE) model for Ningaloo Marine Park and the Gascoyne Region in general. The research program of the Cluster complemented that undertaken through WAMSI and collectively these two programs, along with core research undertaken by the Australian Institute of Marine Science (AIMS) at Ningaloo, have become known as the Ningaloo Research Program (NRP). The department is working together with representatives from the Cluster and AIMS to ensure the research program will meet management needs and be properly integrated and communicated to those who will use it.

The science plan for Node 3 of WAMSI consists of six main projects, each led by a different institution. Thus the coordination and administration role entails ensuring that all project plans are functioning according to the agreed outputs and timeframes. A key focus of this project is to ensure the transfer and uptake of knowledge generated through the research into departmental management policies, practices and actions.

Aims

- Ensure the coordination and administration of the research program.
- Ensure the integration of this research program with other research within WAMSI and with external programs relevant to Ningaloo Marine Park.
- Ensure the outputs of research undertaken through the NRP reach target audiences.
- Ensure that knowledge transfer and uptake occurs between scientists, resource managers and decision makers.
- Ensure the long-term storage and custodianship of data from the research undertaken.
- Evaluate the effectiveness of the knowledge transfer and uptake process so that lessons learned can be applied to future WAMSI and departmental research programs.

Progress

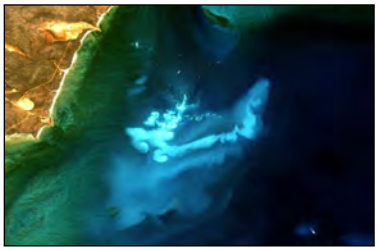
- A final report providing an evaluation of changes to social capital associated with the Ningaloo Research Program was completed and the results of this study were published in the journal *Marine Policy*.

Management implications

- Science has a key role in increasing community trust in decision makers and decision making processes when communicated well to the local community.
- Knowledge exchange at the end of a research program is an important final task that will enhance the appreciation for and uptake of new knowledge and its use by managers and by the local community.

Future directions

- The project is now complete.



Effects of Gorgon project dredging on the marine biodiversity of the Montebello/Barrow Islands marine reserves

SP 2010-008

A Kendrick, R Evans, G Shedrawi

Context

The Gorgon project on Barrow Island is the largest single-resource natural gas project ever developed in Australia. The plant includes three 5 million tonne per annum LNG trains, with domestic gas piped to the mainland, and a four kilometre long loading jetty for international shipping. The project included a dredging program that excavated and dumped approximately 7.6 million tonnes of marine sediment over a period of approximately 18 months. The Gorgon Dredging Offset Monitoring Evaluation and Reporting Project (Gorgon MER) investigated the impacts of the dredging and dumping activities on selected marine communities within the Montebello/Barrow Islands marine reserves. This monitoring will also help inform future environmental impact assessments by improving predictions of the spatial scale and nature of the likely impacts of dredging and dumping activities on sensitive marine communities. Additionally, this project will provide significant baseline data for long-term monitoring of key ecological values in the marine reserves.

Aims

- Assess the nature and extent of potential impacts of the Gorgon dredging program on the condition of coral, fish and other important ecological communities of the Barrow/Montebello islands marine reserves.
- Determine the cause/s of any changes in the condition of the above communities, with particular focus on dredging, dumping and re-suspension of spoil.
- Assess the effects of potential confounding natural (e.g. cyclones, disease, predation, bleaching) and other anthropogenic (e.g. fishing) pressures on the condition of coral communities of the Barrow/Montebello islands marine reserves.
- Assess the nature and extent of the impacts from the Gorgon dredging program on the social values of the Barrow/Montebello islands marine reserves.

Progress

- Progress was made on the completion of data analyses and finalising the final report.

Management implications

- Phase One of the Gorgon MER project provides department managers and scientists with a relatively intensive baseline for assessing potential impacts on, and recovery of, coral communities within the MBIMPA, with a particular focus on potential impacts related to the dredging program for the Gorgon Project. Information outputs include temporal condition and related pressure measures for biophysical assets (e.g. coral, finfish and macro-invertebrate communities) that aligns with the department's marine monitoring program for the MBIMPA.
- The data generated from this monitoring program complements Offset E of the Pluto Energy LNG program aimed at improving the capacity of government and industry to manage the impacts of dredging on

tropical coral reef communities. The Gorgon MER project also strategically assists the planning for future environmental impact assessments by improving predictions of the spatial scale and nature of the likely impacts of dredging and dumping activities on sensitive marine communities.

Future directions

- The project will be completed with delivery of the final report.

Spatial and temporal patterns in benthic invertebrate communities of the Walpole and Nornalup Inlets Marine Park

SP 2009-013

S Strydom, M Rule, A Kendrick

Context

Walpole and Nornalup Inlets Marine Park (WNIMP) was created in 2009 to include the entrance channel, Walpole and Nornalup inlet basins and the tidal extent of the Frankland, Deep and Walpole rivers. Invertebrates are recognised as a significant ecological value of the marine park and a key performance indicator (KPI) of management effectiveness. Additionally, benthic invertebrates are a key food source for a range of fish species in WNIMP. The benthic invertebrate community of the inlets was initially described from surveys conducted in 1984 and 1987. The fauna was relatively diverse compared with most estuaries in the south-west of Western Australia because of the predominantly marine conditions that are sustained in the inlets. Few subsequent studies have examined this fauna, and the current knowledge of benthic invertebrates in the system is considered to be inadequate for marine reserve management. Furthermore, as there are strong recreational fishing values associated with the region, understanding trophic links between benthic invertebrates and fishes in the estuary is important for management of the marine park.

Aims

- Determine spatial patterns in the WNIMP benthic invertebrate community.
- Determine temporal variation in the WNIMP benthic invertebrate community, particularly in relation to seasonal changes in the hydrological cycle of the inlet system.
- Assist to develop methods for long-term monitoring of benthic invertebrates in WNIMP and more broadly across temperate estuarine marine protected areas.
- Determine whether there are spatial and temporal difference in fish community structure (i.e. species composition, abundance, age class) in WNIMP.

Progress

- A collaborative DBCA/Edith Cowan University (ECU) student camp was held at WNIMP in April 2018. Third year undergraduate students studying Coastal and Marine Management with Professor Paul Lavery collected data on fish within the estuary to examine broader ecosystem links with the invertebrate community.
- These data will be analysed with the invertebrate data set collected from previous years after the third sampling trip of this type, which is planned for April 2019.
- Local Parks and Wildlife Service Rangers worked on the sampling with Marine Science Program staff and ECU researchers and students, which has provided educational opportunities to teach students about the values and management of WNIMP.

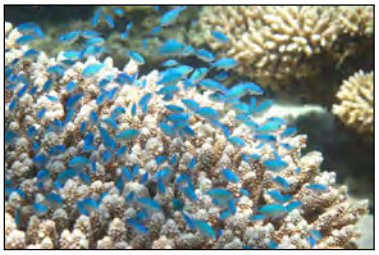
Management implications

- As benthic invertebrates are a KPI for this marine reserve, knowledge of spatial and temporal patterns in their distribution is important to understanding the condition of this community in relation to the influence of natural processes and possible anthropogenic impacts.

- This study will assist the implementation of long-term benthic invertebrate community monitoring at WNIMP.

Future directions

- Finish sampling associated with the current three-year program.
- Analyse several large data sets and prepare reports and manuscripts for publication.



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

- The loss of coral following bleaching alters the type of habitat available for fish, which can have a direct effect on their health and survival. Data analysis shows shifts from coral to macroalgal dominated states alters the trophic structure of fish assemblages, such that herbivores and large bodied invertebrate feeders are more prominent and small bodied dietary specialists are less common. A paper has been published in *Ecological Applications*.
- Analysis has revealed that predatory fish on macroalgal-dominated reefs feed further down the food chain and this affects their physiological condition and can jeopardise long-term survival. A paper was published in *Functional Ecology*.
- The loss of coral due to mass bleaching will also limit reef growth, and modelling predicts that few reefs have the capacity to grow fast enough to keep pace with projected increases in sea level rise, compromising their ability to protect coastlines and shallow water habitats from wave energy. A paper was published in *Nature*.
- Analysis of data following the 2016 El Niño event, has shown that mass bleaching events caused by warm water anomalies are becoming more frequent since the 1980s and are now expected about every six years. This work was published in a paper in *Science*.
- Data from this study continue to be used in national and international collaborations.

Management implications

- Coral bleaching is likely to become more frequent, which will alter the ecological function and services coral reefs provide. This includes diminished capacity to shelter coastlines from wave energy and changes to the fish assemblages which may affect local fisheries and the ecological role fish play on reefs.
- Management intervention is increasingly posed as an option for mitigating the effects of climate change on coral reefs; however, the ecological risks and consequences associated with these actions are poorly understood. The data from this study will contribute to risk assessments and/or experiments required for a broader appreciation of how such interventions may impact on Western Australia's marine reserves.

Future directions

- Finalise a statewide assessment of bleaching impacts on corals following the 2016 El Nino event.

Spatial and temporal patterns in the structure of intertidal reef communities in the marine parks of south-western Australia

SP 2009-002

S Strydom, M Rule, A Kendrick, J Huisman, B French

Context

Marmion Marine Park (MMP) and Shoalwater Islands Marine Park (SIMP) are located on the north and south Perth metropolitan coast, respectively, while Ngari Capes Marine Park (NCMP) is in Western Australia's south-west. These marine parks support a diverse range of marine conservation values ranging from various marine habitats to threatened marine fauna, and are dominated by sub-tidal and emergent limestone reefs and shallow sandy embayments. The marine parks are subject to high levels of recreational and commercial human activity due to their proximity to population centres. Significant areas of intertidal reef platform occur in both mainland and island shores and as isolated offshore patch reefs. While a number of local studies of intertidal communities provide a significant regional knowledge base, the broad spatial patterns of intertidal biodiversity across MMP, SIMP and NCMP are not adequately understood. Particular gaps exist in our knowledge of the intertidal communities of offshore platform reefs. This study will determine spatial and temporal patterns in the distribution of intertidal reef organisms in Western Australia's temperate marine reserves. Relationships between the composition of these communities and the physical structure and location of the reefs will also be examined.

Aims

- Determine spatial and temporal patterns in the composition of intertidal reef communities in MMP, SIMP and NCMP, including the proposed northern extension to SIMP.
- Determine if the intertidal reef communities in management zones protected from extractive activities differ from the intertidal reef communities of otherwise comparable reefs.
- Assist in the development of methods for long-term monitoring of intertidal communities in temperate marine reserves.

Progress

- A paper describing differences in community structure on intertidal granite and limestone substrates at Ngari Capes Marine Park has been accepted for publication in the journal *Marine and Freshwater Research*.
- Analysis of other data sets is continuing.

Management implications

- As the first comprehensive spatial and temporal study of the biological communities associated with intertidal reefs of Western Australia's temperate marine parks and reserves, this work provides a baseline

understanding of intertidal reef condition in the marine reserves in relation to natural processes and possible anthropogenic impacts. The results will assist with ascertaining the conservation significance of these habitats and assist the implementation of long-term intertidal reef monitoring and management.

Future directions

- Ecological papers from data collected in MMP, SIMP and NCMP will be published.
- A species identification guide to assist future intertidal reef monitoring will be completed.
- Further surveys of intertidal reef communities at NCMP are planned.

Fire Science

Program Leader: Lachie Mccaw 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.

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

SP 2018-046

B Miller, K Ruthrof

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 federally 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

- Baseline pre-treatment data have been collected from six sites - Kings Park, Bold Park, Jandakot and Beeliar Regional Parks, Murdoch bushland and Geraldton's Byrne Park
- Burn implementation and follow-up weed management has occurred at the Murdoch site. Follow-up weed management was undertaken at Kings Park, Bold Park and Jandakot following burns in 2015, 2016 and 2015 respectively.
- Annual monitoring has occurred at each site after treatment.
- Initial, early results confirm: the positive response of grassy weeds in particular to burning; a negative consequence of high grass cover for native fire-ephemeral species; and the importance and efficacy of post-fire weed intervention.

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

- Initial treatments for the Murdoch and Geraldton sites are planned.
- Preliminary analysis of existing initial response data will be undertaken as a burn x weed treatment.
- Analysis of fuel and structure data with supplementary work including biomass harvesting and plant allometry.
- Ongoing identification of new sites for inclusion in the study

Understanding the changing fire environment of south-west Western Australia

SP 2014-001

V Densmore, L McCaw, 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 manuscript examining meteorological drivers of extreme fire behaviour during the 2016 Waroona bushfire was published in the *Journal of Southern Hemisphere Earth Systems Sciences*.
- Factors contributing to extreme fire behaviour during a prescribed burn at Table Hill forest block near Rocky Gully in November 2017 were investigated to understand the contributions of atmospheric instability, fuel conditions and ignition pattern. The Table Hill incident will provide a case study to evaluate the applicability of a conceptual model for blow-up fire behaviour.
- Forty years of fire report data from the Warren region were analysed to examine trends in temporal and spatial patterns of lightning ignition. Lightning ignition activity has increased since 2002, particularly during spring. A manuscript reporting findings from the study is in review.
- In conjunction with Warren Region and Fire Management Services Branch, an adaptive management program has been developed to facilitate and evaluate prescribed burning in young regrowth stands of jarrah and karri. Achievement of prescribed burning objectives is being monitored using ground-based methods and assessment of burn severity derived from satellite remote sensing, where possible linked to existing FORESTCHECK monitoring. Field surveys were undertaken at a number of sites to quantify post-fire response of tree species.
- An oral paper was presented at the Tenth Australasian Natural Hazards Management conference held in Perth in November 2017.

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

- Continue to support the Bushfire and Natural Hazards CRC study modelling coupled fire atmosphere interactions during the 2016 Waroona bushfire.
- Finalise publication of the manuscript analysing temporal and spatial patterns of lightning ignition for the Warren Region, and continue to investigate regional climatic drivers of lightning ignition in collaboration with Bureau of Meteorology and CSIRO.
- Harness existing data on fuel moisture content to evaluate and calibrate new measures of landscape dryness available from numerical weather prediction modelling, including outputs from JASMIN (Data Processing Environment) and the Australian Landscape Water Balance model.
- Continue monitoring and reporting on outcomes of the adaptive management trial of prescribed burning in regrowth forest.

Fire behavior and fuel dynamics in coastal shrublands

SP 2012-036

K Knox, L Mccaw

Context

Shrubland ecosystems are widespread in south-western Australia and are the predominant vegetation type in coastal areas between Geraldton and Esperance. Coastal shrublands are renowned for their flammability, and fires can be fast-moving and intense when dead fine fuels are dry and wind speeds exceed 15 km per hour. Fires may transition abruptly from the litter layer to the shrub layer in response to minor changes in wind speed and fuel dryness, making it difficult to use prescribed fire reliably to meet management objectives. Currently the department does not have a fire behaviour prediction guide specific to coastal shrublands, and this represents a significant gap in science-based decision making to underpin the use of fire for bushfire risk management and biodiversity conservation. This issue was highlighted by the Special Inquiry into the November 2011 Margaret River bushfire conducted by the Hon. Mick Keelty. This project addresses Recommendation 4 of the Keelty Special Inquiry that the department be supported to conduct further research into the fuel management of coastal heath in the south-west of Western Australia exploring alternatives to burning as well as best practice for burning.

Aims

- Provide a systematic approach for describing fuel characteristics and predicting fire behaviour in coastal shrublands in order to more effectively manage prescribed burning and bushfires.
- Facilitate evaluation of the effectiveness of prescribed fire and other fuel management practices for mitigating the impact of bushfires.

Progress

- A paper examining fire behaviour during the November 2015 Two Peoples Bay bushfire was submitted for publication.
- Monthly sampling of live foliage moisture content was undertaken for a second year at Yanchep as part of a study evaluating the potential application of remote sensing to quantify dryness and flammability in coastal shrublands.

Management implications

- Development of a systematic approach to describing fuels and predicting fire behaviour in coastal shrublands will permit the implementation of better informed fire management programs in this habitat that is a critical component of urban environments.
- Improved knowledge of factors determining fire behaviour in shrublands will contribute to more effective training programs for fire managers and fire-fighters from the department and other organisations with responsibility for fire preparedness, management and suppression.

Future directions

- Analyse and publish the findings from the study of remote sensing of live fuel moisture content.
- Collect fire behaviour metrics from planned burns to verify the performance of the collaboratively-developed fire spread model for Western Australian shrublands.

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

SP 2012-029

N Burrows, 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.

Progress

- A manuscript has been prepared and submitted to *Fire Ecology* and is currently being revised.
- Data analysis showed that species richness declines with time since fire but no effect of fire treatment on species richness was detected.
- No fire treatment effect on species assemblage composition was detected after accounting for time since fire and elapsed time.
- Assemblage composition changes with elapsed time, consistent with the theory of ecological drift.
- Changes at the plant fire response level do not drive assemblage changes.
- Excluding grazing from the Yackelup forest site increased species richness with elapsed time. Grazing exclosures at Yackelup were repaired to maintain the integrity of the experimental site into the future.

Management implications

- Being one of a few long-term studies of its kind around the world, the findings of this study will be 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.

Future directions

- Revise and publish paper.

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% capture rate, or decline of mean shrub projected ground cover to <2%.
- 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

- Recent work comparing mammal populations before and after fire programs show that larger marsupials and arboreal species including brush-tailed rabbit rat and the golden backed tree rat have benefited from patchy early dry season burning and increased in abundance.
- Populations of native rodents including pale field rats and chestnut mice have stabilised in response to early dry season burning and reduced annual fire variability. This signals a change from the cycle of boom and bust dynamics that typified the period prior to the commencement of the LCI.
- Following monitoring in 2018, most sites will have at least five years of data available for analysis, enabling a comprehensive evaluation of the effectiveness of management on conservation reserves across the north Kimberley.

Management implications

- 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.
- There is statistical evidence that the LCI has shifted the fire regimes in the Mitchell and North Kimberley bioregions from a dominance by late dry season bushfires to predominantly early dry season prescribed burning, with positive benefits to threatened mammals.
- Data on mammal decline and snake increases in Mirima/Kununurra suggest a previously unappreciated mechanism for mammal decline. This implies that the impact of cane toads is more complex than previously thought and that fire management and cattle culling will be insufficient on their own to prevent future mammal declines in the north Kimberley.

Future directions

- Monitoring and evaluation will continue to demonstrate ongoing management effectiveness of the LCI.
- Evaluation of factors influencing mammal abundance and richness between years will be undertaken using statistical modelling approaches.
- Investigate the response of obligate seeder plants to a systematic ignition approach being trialled for fire management in some remote parks.

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 arguably 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 scientists with expertise in the region each 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 major 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 very 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 and development of ecosystem structure.
- Measure fuel and carbon dynamics with time since fire in gimlet woodland.

Progress

- A multi-century time since fire chronosequence of 76 plots has been established in gimlet woodlands, sampling plant composition, vegetation structure, visual fuel assessment, ants, birds and carbon stocks.
- Data from the chronosequence have been used to: (i) develop a conceptual model of vegetation dynamics for the unique obligate-seeder temperate eucalypt woodlands of southwestern Australia and a paper was published in *Austral Ecology*; (ii) review the composition, biogeography, environmental correlates and ecology of Australia's temperate eucalypt woodlands and a chapter was published in the book *Australian Vegetation*; and (iii) determine the effect of time since fire on the abundance and composition of woodland bird communities, with a particular focus on birds that have declined following habitat loss and fragmentation in eucalypt woodlands of the Western Australian wheatbelt and a paper is in review.
- Draft manuscripts have been prepared presenting a revised model for estimating the time since fire in long-unburnt gimlet woodlands, and changes in standing and coarse woody debris stocks with time since fire.

Management implications

- National-scale syntheses of temperate eucalypt woodland fire ecology 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 illustrative a putative vulnerability to decreases in intervals between fires, providing information to support fire management regimes.
- Post-fire succession in plant 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.

- Changes in vegetation structure and cover, and fire probability based on historical fire records, indicate maximum gimlet woodland flammability at intermediate times since fire, supporting the revision of fire behaviour ratings.
- Woodland bird species that have declined following habitat loss and fragmentation in the Western Australian wheatbelt are strongly associated with long-unburnt woodlands, providing information on appropriate woodland fire management regimes that support persistence of populations of these species.
- Knowledge generated through this project has been incorporated into fire ecology training 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 bird communities and coarse woody debris with time since fire.
- Collect additional field data on carbon stocks to provide more precise estimates of changes with time since fire and prior fire interval.
- Investigate methodological options for correlating location-based estimates of gimlet woodland time since fire to remotely-sensed spectral values, with the aim of developing a spatially-explicit woodland age-class distribution.

Burning for biodiversity: Walpole fine-grain mosaic burning trial

SP 2004-004

N Burrows, J Farr, G Liddelow, 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 the operational techniques to be able to use frequent and planned introduction of fire into the landscape (patch-burning) to create a fine-scale mosaic of patches of vegetation at different stages of post-fire development.

Progress

- Field work has been completed for this project. Data are being compiled, fungi and invertebrate collections have been sorted and documented. Data for invertebrates has been compiled and analysis has commenced.
- Collaboration with a US-based FRAGSTAT statistician has been very helpful in analysing landscape-scale fire mosaics.
- Papers on the effects of mosaic burning on cryptogams have been published in the *Journal of the Royal Society of Western Australia*and *Fire Ecology*.
- A paper describing the theory of fire-induced mosaics, how to describe and characterise mosaics, and operational challenges in creating fire mosaics is being prepared for publication.
- A draft manuscript describing effects of mosaics and responses to time since fire in bird assemblages 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 invertebrates and fungi, 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 data analysis and publish papers.
- 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

CF 2018-085

D Merritt, T Erickson

Context

Seed science encompasses fundamental and applied research on the physiology and ecology of seed dormancy, germination, and longevity to facilitate the use of seeds for conservation and ecological restoration purposes. 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.

The development of seed technologies to improve seed conservation, plant propagation and landscape-scale ecosystem restoration is a major emphasis of the research. Multi-disciplinary partnerships including those with soil scientists, plant physiologists and engineers are fundamental to developing capacity for seed-based restoration of biodiverse plant communities on degraded landscapes.

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.

Progress

- Automated and high-throughput closed system respirometry was developed to examine the relationship between seed mass, dormancy type, and basal metabolic rate for more than 70 species as part of developing seed respirometry to predict seed longevity in storage.
- New methods of seed enhancement were developed through bio-priming of seeds with naturally occurring cyanobacteria to enhance seed germination and the potential for initiating microbial activity and increasing soil carbon in mine waste substrates.
- Design and engineering of seed-treatment equipment was refined, focussing on the flash-flaming of seeds to enhance their geometric properties for seed coating and for precision seeding through mechanised seeders.

Management implications

- Novel methods and data handling techniques for high-throughput respirometry analyses of seeds means these respirometry techniques can now be applied to questions related to the prediction of seed longevity in storage.
- Soil carbon, soil microbial activity, and soil water holding capacity are important limiting components of the mine-wastes that form the basis of rehabilitation substrates. The priming or pelleting of seeds with naturally occurring cyanobacteria may provide a method of reconstructing soil functionality to support enhanced seedling establishment.

Future directions

- Laboratory trials will continue to refine the use of seed respirometry to predict seed longevity, including a comparison of the accuracy of measuring basal metabolic rates versus metabolic rates of actively germinating seeds.
- Field trials in the Pilbara over the next year will examine the effects of the application of inorganic and organic soil amendments to mine waste substrates on seedling emergence.
- Projects on the engineering of seed equipment will focus on the design and construction of a second, improved flash flaming unit for removal of seed appendages to allow for coating/pelleting.
- Testing of initial modifications to direct seeding machinery to evaluate precision of seed delivery under field conditions in the Pilbara.

Restoration science

CF 2018-077

J Stevens, S Krauss, W Lewandrowski, C Elliott, M Barrett

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

- Substrate hydrological dynamics were defined for restored pasture systems after bauxite extraction.
- Recruitment and establishment bottlenecks were quantified for *Banksia* woodland and Banded Iron Formation species.
- Initial methods were developed to establish a link between ecophysiological performance of seedlings and near surface remote sensing spectral indices.
- The role of biotic inoculants on drought stress tolerance of native species was investigated.
- Identification of links between seed provenance and establishment success in *Banksia* woodland systems.
- Leaf traits and their interactions with dust impacts were assessed in the context of Banded Iron Formation mining.

Management implications

- The ability to understand recruitment dynamics in altered substrates will inevitably dictate restoration trajectories. For restoration programs that can manipulate or remake substrates, understanding the hydrological and biological dynamics of the system and how they interact with plant water requirements for germination, establishment and productivity will drive restoration trajectories.
- Monitoring restoration programs to understand plant function at the scale now required may mean introducing new technologies to complement traditional monitoring methods. Linkage of plant function to remote sensing spectral signatures and more distant sensing technologies will provide a basis and define levels of confidence for broad scale future use.

Future directions

- Continue to develop near surface remote sensing technologies and linking these to plant ecophysiological performance and water status.
- Further research to decipher biotic (plant and micro-organism) interactions in restoration will be undertaken to define the importance of local provenance plants and local fungi/bacteria underpinning plant function and ecosystem reassembly in restoration environments.

Conservation genetics

CF 2018-068

S Krauss, J Anthony, M Barrett, E Sinclair

Context

The conservation and restoration of Western Australia's unique biodiversity is underpinned by genetics research that aims to understand the ecological requirements of native flora and their genetic vulnerabilities to threats, including mining activities. Such research provides information on genetic diversity, population and species relationships, mating system and pollen dispersal to support restoration, conservation, population management and taxonomy.

Aims

- Quantify the potential genetic impacts of mining on threatened flora.
- 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.
- Quantify genetic diversity and its spatial structure for conservation and restoration priority taxa including *Triodia* and *Posidonia*.
- Experimentally assess the resilience of plant populations to environmental stressors.
- Conduct taxonomic revision and survey in key taxa including *Triodia*, and regions such as the Kimberley.

Progress

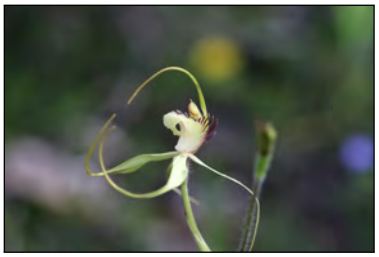
- The potential genetic impact of proposed mining activities on the threatened plant species *Tetratheca erubescens* and *Ricinocarpus brevis* was quantified and results published in *Australian Journal of Botany*.
- Seed sourcing strategies for ecological restoration under current and future climates were assessed for *Banksia menziesii* through large-scale field-based provenance trials across the Swan Coastal Plain.
- The extent and significance of negative genetic effects following the mixing of seed source provenances for ecological restoration was experimentally assessed for *Stylidium* spp. in the northern jarrah forest, with evidence for inbreeding depression and outbreeding depression at a landscape scale.
- The consequences of nectar-feeding birds as pollinators for eucalypts, banksias, kangaroo paws and catspaws was assessed and the implications were that bird pollination results in high multiple paternity and wide outcrossing for the plants they pollinate. Some species assessed showed highly specialised relationship with bird pollinators, such that impacts on birds can have significant consequences for plant reproduction.
- Connectivity, reproductive functionality and delivery of pollinator services in restored populations of banksias pollinated by vertebrates was confirmed and results were published in *Restoration Ecology*. Results show that highly mobile bird pollinators move freely into restored banksia populations.
- Range-wide genetic diversity and its spatial structure, mating systems, long-distance seed dispersal, and movement ecology was described for seagrass (*Posidonia*). Results indicated complete outcrossing and extensive dispersal of seed that is influenced by the local ecological environment.
- The adaptation and resilience to climate change in seagrass was assessed. Preliminary results suggest adaptation and resilience to climate change in seagrass, assessed through reciprocal transplant trials and genomic analysis for meadows occupying a strong environmental gradient in Shark Bay.
- A redefinition of biologically significant units in spinifex (*Triodia* spp.) provided improved ecological restoration in arid Australia. Results include the description of multiple new species, identification of cryptic ploidy variation across species distributions, and an identification app for practitioners.
- The conservation and restoration implications of DNA ploidy variation in sedges and grasses were described, with results published in *Australian Journal of Botany*.
- Genetic erosion in the 20-year translocation recovery of the critically endangered species *Grevillea scapigera* was described and strategies to address genetic erosion were identified and implemented.
- Soil microbial diversity trajectories following post-impact rehabilitation were quantified using high-throughput DNA barcoding methods. Results indicated that restored soil biota trajectories and diversity are returning towards the undisturbed soils, but even after 30-years key elements are still missing.
- Genetic diversity and structure of plants endemic to banded ironstone formations in Western Australia was reviewed. Persistence and stochasticity were found to be key determinants of genetic variation and its spatial structure for these flora.

Management implications

- Seed sourcing guidelines developed for the Swan Coastal Plain improve restoration outcomes through the genetic delineation of locally adapted provenance zones for multiple species.
- Effectiveness of in situ and ex situ management can be improved through manipulating spatial genetic structure to maximise outcrossing and avoid genetic effects associated with inbreeding.
- Clarity on the taxonomy and distribution of genetic diversity for key taxa of restoration significance informed restoration practitioner guidelines on seed sourcing that improved restoration outcomes through appropriate matching of species and/or provenances to restoration sites.

Future directions

- Assess conservation genetic consequences of vertebrate pollination for *Anigozanthos manglesii, A. humilis, Eucalyptus caesia, Banksia ilicifolia, B. menziesii* and *B. attenuata* through molecular and ecological studies.
- Assess population genetic variation and mating system of the threatened flora *Styphelia longissima*.
- Continue to assess the resilience of seagrass to environmental stressors through reciprocal transplant trials in Shark Bay, population genomic analysis, and controlled manipulative experiments.
- Continue to assess seed sourcing for restoration strategies through large scale provenance trials, glasshouse trials, and seed germination trials for *Banksia menziesii, B. attenuata* and *Eucalyptus todtiana*, which are key species for ecological restoration on the Swan Coastal Plain.
- Assess delivery of vertebrate pollinator services as a measure of restoration success for multiple species in post-mine site rehabilitation at Eneabba.



Orchid conservation and recovery

CF 2018-060

B Davis, B Miller, 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.
- Conduct integrated conservation research to provide management solutions to improve the conservation status of threatened orchid taxa.
- Collect seed and fungal isolates of *Caladenia busselliana*, a Critically Endangered species from the Busselton area, and propagate *C. busselliana* seedlings in preparation for *in situ* population supplementation and/or translocation program.
- Make collections of seed and fungi from *Caladenia lodgeana*, *C. procera* (Critically Endangered) and *C. viridescens* (Endangered) to investigate potential for supplementation of wild populations and *ex situ* storage.

Progress

- Seed was collected from the four remaining and known wild populations of *C. busselliana*.
- Representative fungal isolates were collected and cultured successfully.
- Isolates screened for germination efficacy and will continue to be monitored for effects on growth and re-emergence.

- Nine hundred *C. busselliana* seedlings propagated and currently in transition from laboratory to glasshouse.
- Site selection for translocation currently being investigated based on likely presence of mycorrhizal partner, site security and microhabitat matching.

Management implications

- The *ex situ* insurance population of *C. busselliana* provides essential conservation support for this critically endangered species with total plant numbers now increased many times over.
- The protocol for propagation of threatened orchids and maintenance of collections of associated mycorrhizal partners will demonstrate and improve capability transferable to other threatened orchid taxa.
- Improved protocols for tuberisation, seedling transfer from laboratory to soil, and field translocation will directly assist conservation for *C. busselliana*, and build capability for other threatened taxa.
- Knowledge to support orchid conservation and translocation will be improved.

Future directions

- Optimise propagation protocols to increase supplementation success from laboratory to *in situ* site.
- Progress fungal isolate screening for *C. viridescens* and *C. procera* along with propagation of seedlings.
- 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

CF 2018-048

R Bunn

Context

Research into *in vitro* and cryogenic science is required to support *ex situ* conservation and germplasm storage of threatened plants. 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 taxa, as well as seeds and mycorrhizal fungi of 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

- Research continued into developing *in vitro* propagation and cryogenic protocols for Western Australian threatened plants, including *Symonanthus bancroftii*, *Acacia leptoneura*, *A. subflexuosa* subsp. *capillata*, *Conospermum galeatum*, *Banksia montana*, *Lasiopetalum moullean* and *Eucalyptus phylacis*.
- Threatened species cryo-banking research continued on the following rare species; *Philotheca basistyla*, *Synaphea quartzitica*, S. *stenoloba*, *C. galeatum*, *Styphelia longissima*, *Eremophila virens*, *B. serratuloides* subsp. *perissa*, *E. dolorosa*, *Allocasuarina fibrosa* and *L. moulleans,* with emphasis on cryo-banking multiple genotypes.
- A review paper on cryopreservation of Australian plant species was submitted to *Australian Journal of Botany*. This paper highlights advances in cryogenic storage of plant tissues worldwide and also discusses the application of plant cryopreservation from an Australian perspective.

- A conference paper entitled: 'Current progress in understanding cryopreservation effects on oxidative stress and metabolism in shoot tips of Western Australian species, using a combined biophysical and metabolomic approach' was presented at the XIX International Botanical Congress, Shenzhen, China.

Management implications

- In vitro propagation provides a 'safety net' for threatened species in dire 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℃) for endangered 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℃) 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.
- Work with colleagues from the Plant Science and Herbarium Program and the Parks and Wildlife Service to identify priority threatened species, in particular orchids, in need of biotechnological solution to support *in situ* management actions and long term *ex situ* conservation.

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 captive breeding program

SP 2018-137

K Bradfield

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 the 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 be bred in captivity, as this knowledge will inform future recovery actions.
- To develop and document captive breeding techniques that maximize 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

- One breeding pair was established and produced three clutches of eggs for a total of 11 eggs. Only one egg in the first clutch was fertile, but development of the embryo ceased at around six days into

the incubation period. Not all of the eggs were considered high quality, as they had low egg weight and unusual shape.
- Observation of feeding and breeding behaviour have provided valuable insights into the biology of the species and its requirements in captivity.

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
- Acquire additional birds and an expanded genetic base to the colony, to ensure persistence of the captive colony.

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

CF 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
- Bespoke dataloggers have been manufactured and are ready for deployment during the 2018-19 summer months.

Management implications
- Gaining specific information regarding the temperature and forces applied to packages travelling along postage routes from remote Western Australian townsites 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

- Dataloggers will be deployed during the summer of 2018-19, and the resulting data will be analysed for the publication of a manuscript.

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

CF 2018-115

P Mawson

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 Zoo 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.
- Data from behavioural observations on both Sumatran tigers has contributed to a new exhibit swapping enrichment regime, with observations continuing to monitor behaviour post-regime change.
- The solo lioness continues to be monitored during Phase 2 of the construction of the new lion exhibit.
- A team of docents continued to review overnight Asian elephant CCTV footage and to record the sleeping habits of elderly female elephant 'Tricia'.
- Observations continued on the behaviour of male orangutan 'Dinar' with emphasis on enrichment use, activity levels and behaviours. Comparison will be made between recorded behaviours collected before and after the death of the Perth Zoo's other mature male 'Hsing' early in 2018.
- Observations are being recorded throughout the African savannah precinct to gain information on the behaviour and location of animals in relation to time of day, weather conditions and staff and visitor activity. These observations have been designed to also provide information on the visibility of the African Savannah collection animals from specific visitor viewing areas.

Management implications

- Empirical behavioural data gathered through this project allow 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 the interaction between the Zoo's existing 19 year-old lioness and the two new lionesses that will be imported in October 2018; monitor breeding behaviour in golden lion tamarins; monitor behaviour in the dominant male and the mother-offspring behavioural interactions in orangutans; monitor sleeping patterns in Tricia the elephant and nocturnal activity levels in the Zoo's other two elephants.

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. vitelllina*, 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. Eggs 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. vitelllina* was maintained. Eggs 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.

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. Captive reared frogs are available in great enough numbers to re-establish populations at sites where local extinctions have occurred or to establish new populations where suitable habitat exists but no populations have previously been recorded. This approach contributes to effective management and maintenance of the wild population.

Future directions

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

Western swamp tortoise breed for release program

CF 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

- Thirty western swamp tortoise juveniles were released into swamp habitat at Moore River Nature Reserve. A total of 81 eggs were produced in the captive breeding colony, 54 of which hatched and 47 of which survived to >30 days of age. A research paper describing sexually dimorphic growth in western swamp tortoise was submitted for publication.

Management implications

- The program has released 184 juvenile western swamp tortoises into Moore River Nature Reserve, yet the extended time it takes animals to reach sexual maturity (10-15 years after release) combined with natural mortality rates, means that the estimated adult population at this site is only around 10-12 individuals. Nesting behaviour and hatchlings have been observed in this new population, indicating breeding that may lead to the establishment of a self-sustaining population.

Future directions

- Continue to produce juvenile animals for release to sites approved by the Western Swamp Tortoise Recovery Team.

Dibbler breed for release program

CF 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 achieed 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 at further self-sustaining populations.
- Carry out genetic monitoring and management of reintroduced populations.

Progress

- In October 2017, 63 captive bred juvenile and six adult dibblers were released into Peniup Nature Reserve. This release included all of the breeding stock and was designed to make way for the acquisition of a new blood line derived from the dibblers collected from three Jurien Bay islands.
- Population levels on two of the three islands were assessed in 2017-18 and were deemed too small to sustain the removal of the proposed number of animals and none were provided to Perth Zoo, therefore no dibblers were produced during the autumn 2018 breeding season.

Management implications

- The release of dibblers into Peniup Nature reserve will bolster this new mainland population.
- The lack of founding stock from Jurien Bay islands means that the proposed reintroduction of dibblers to Dirk Hartog Island National Park as part of the the *Return to 1616* program will be delayed by one year.

Future directions

- Breed dibblers if founders from the Jurien Bay islands are available.

Numbat breed for release program

CF 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 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 19 yearling numbats for release into the Australian Wildlife Conservancy's Mount Gibson Sanctuary. The numbats released in December 2017 at Mount Gibson represented the second year's release into a secure, feral-predator free sanctuary in a three-year approved translocation program involving captive-bred numbats.

- An additional wild-born adult numbat surplus to the breeding program requirements was returned to Dryandra Woodland at the conclusion of the breeding season.
- Three male and one female numbat were provided to the program from Dryandra Woodland to maintain the genetic integrity of the breeding program.

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

- Following the release of additional numbats in December 2018, the reintroduction program for the Mount Gibson Sanctuary will be complete.
- The Numbat Recovery Team is considering requests for the release of numbats into new reintroduction sites.

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 are Endangered, one is Vulnerable), and all are the subject of 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.

This project has seen the successful release of 542 rehabilitated cockatoos from three species, 290 Carnaby's cockatoo, 60 Baudin's cockatoo and 192 forest red-tailed black cockatoo. The total number of cockatoos leg banded (all species and all ages) is now 1,458 from 15 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. Project success will be built on to investigate patterns of habitat usage and colonisation, to better understand distribution and further contribute to the management of black cockatoos on the Swan Coastal Plain.

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

- During 2017-18, 134 (116 as pullus, three adults and 15 rehabilitated) Carnaby's cockatoos were banded, along with 44 forest red-tailed black cockatoos (one as pullus and 43 rehabilitated).

- One hundred and three Carnaby's cockatoos, one Baudin's cockatoo and seven forest red-tailed black cockatoo were either retrapped/recovered, had their bands photographed in the field and their band number read or inferred, or the satellite transmitters were recovered when tail feathers were moulted in autumn 2018.
- A significant record was obtained this year with an adult male Carnaby's cockatoo having its band read in the field for the first time in just under 28 years.
- A research paper on nest site fidelity and mate infidelity in Carnaby's cockatoo was published in *Ibis*.

Management implications

- The discovery that 25% of nestlings are sired by males other than the nominal 'father' has important implications for the maintenance of gene pools within local breeding populations, particularly those that are now reduced to only a few pairs. The wider implications of this mating strategy remain to be determined, and will depend on the degree of movement of birds from natal areas into other breeding populations.
- The release of more than 500 rehabilitated black cockatoos provides a significant augmentation of adult numbers for all three species, and given the high survival rates indicates that this conservation action has an important role to play in the management of all three species.

Future directions

- Refine the method used to determine the health of nestlings, and analyse data on the use of artificial nest hollows by Carnaby's cockatoos, and the costs-benefits associated with the rehabilitation of all three species of black cockatoos.
- This 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.
- Using telemetery data from rehabilitated birds to investigate patterns of habitat usage and colonisation, especially for forest red-tailed black cockatoos on the Swan Coastal Plain.

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.

Seagrass monitoring and evaluation

SP 2018-039

J Cosgrove, K Trayler, S Strydom, K Murray

Context

Seagrasses are a highly valued component of estuary ecosystems since they provide habitat, provide a food source for waterbirds and improve water quality by reducing sediment resuspension and removing nutrients. Seagrasses respond to changes in their physical and chemical environment, and worldwide human-impacts have unfortunately led to the loss of much seagrass habitat. Ensuring that seagrass communities remain viable and resilient is an important component of effective estuary management. Since 2011, the department has partnered with the Department of Water and Environmental Regulation to develop and validate a seagrass-based index of 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 and sediment stress.
- Refine and validate the seagrass indicators proposed and provide protocols for the measurement and use of these indicators.

Progress

- A suite of metrics, covering a range of response times and spatial scales, was chosen to inform on seagrass performance and key pressures on seagrass condition.
- Sampling has been successfully conducted across a fifth summer sampling season.
- A final project report has been prepared.
- A paper on functional level indicators of sediment stress for seagrass was published in *Ecological Indicators*.

Management implications

- Identification of a seagrass-based biological index of estuarine health has lead to a better understanding of seagrass community dynamics within the Swan Canning Riverpark and the principal pressures driving these dynamics, thus facilitating provision of more informed advice for the assessment of development applications and in response to public queries.
- The department is considering possible integration of the seagrass index monitoring program, or a variant thereof, into its environmental monitoring program.

Future directions

- Final project report and oral presentation will be delivered in November 2018.

Water Cleanser investigation

SP 2018-035

K Trayler

Context

'Water Cleanser' is a product of the company Marine Easy Clean (MEC), promoted as means to improve water quality in the Swan and Canning Rivers. Curtin University investigations suggest that the product provides a substrate, carbon and trace element source that supports Archaea microbes and particularly *Bacillus* and that, as these microbes accumulate, their biomass provides a catalyst to reset organic matter breakdown and facilitate the nitogen cycle. Replicated tank trials in South America suggest improvements in water quality and anectodal evidence of improved plankton communities in treated tanks. Field application of the product has occurred through many local governments in Western Australia, with anectodal evidence of effective blue-green algal bloom management. Field based trials of this product have lacked adequate replication and evaluation.

Aims

- To test the product in a field setting and evaluate its effectiveness on improving water quality, algal composition and zooplankton abundance.

Progress

- Planning of the project methodology has identified a BACI (before, after, control, impact) nested sampling design (site within treatment) to be applied to test this product.

Management implications

- This project will determine the effectiveness of 'Water Cleanser' on improving water quality, algal composition and zooplankton abundance in a freshwater wetland setting. If the product is found to be effective it could have applicability to water quality improvement on the Swan and Canning Rivers.

Future directions

- Paired wetlands at three locations will be determined with sampling to take place between October 2017 and April 2018. Samples will be taken on three occasions prior to treatment and six occasions over a four month period post treatment.

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 world-wide 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

- To 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 over the summer and autumn of 2018. 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. In turn these were used to calculate and overall index score for each zone.
- A report documenting the 2017 results was released. The report translates index scores (0-100) to quantify ecological health and results are reported as a conceptually simple letter grade (A, very good – E, very poor).

Management implications

- In 2017, the shallow nearshore areas were assessed as being fair to good, while offshore waters of the system were assessed as fair. These results are slightly poorer for 2017 compared with 2016 and reflect the impact of the flood event of February 2017, with associated salinity changes and hypoxia through autumn. Fewer species were caught in 2017 indicating conditions were less favourable for a large number of the marine-associated and estuarine species.
- The ecological consequences of flooding were most evident in the offshore waters of the Middle Swan Estuary, where condition score dropped significantly, from good (B) in summer to poor (D) in autumn. Across the estuary as a whole, the ecological condition based on fish communities has been assessed as generally good to fair in nearshore and offshore waters since 2008 and 2011, respectively.

Future directions

- A report documenting the results of the 2018 sampling will be finalised.

Assessment of multi-wavelength fluorometer technology for chlorophyll *a* and gross phytoplankton composition estimation

SP 2018-032

J Cosgrove

Context

Estimates of chlorophyll *a* (chl-a) concentration derived from fluorometers are currently considered qualitative to semi-quantitative and are not used in any reporting from the Swan Canning monitoring program. However, many national and international water quality monitoring programs use fluorescence-based estimates of chl-a quantitatively as a proxy for phytoplankton biomass. Prime benefits of this method are its low cost and near real-time output. Most programs pair this method with limited pigment and phytoplankton measurements for calibration/verification of fluorescence data. New multi-wavelength instruments that use multiple LEDs of different spectral bands to both more accurately estimate chl-a and provide gross taxonomic characterisation (e.g. cyanobacteria, green, golden-brown (diatoms and dinoflagellates) and cryptophytes) are being applied in the field. This new fluorometer technology will be combined with machine learning techniques to draw the most from the data produced.

Aims

- Assess two multi-wavelength fluorometers for accuracy and precision of chl-a and gross phytoplankton composition estimation.
- Calibrate spectral setting to local species and apply novel machine learning techniques to improve chl-a and community composition estimates.
- Provide an assessment of instrumentation performance in the Swan Canning estuarine system and any potential benefits to environmental monitoring.

Progress

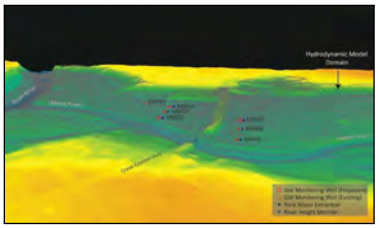
- Fluorometers have been received, setup and representative species have been cultured in preparation for calibration to species specific fluorescence spectra.

Management implications

- Trial of new technologies is important in the review of monitoring approaches for the Swan Canning. Modern measuring techniques can reduce limits of reporting, allow increased sampling frequencies and reduce measurement costs (reducing program budgets or allowing new metrics to be considered).
- If the results of this study are favourable, multi-wavelength fluorometers may substantially improve accuracy of chl-a estimation and provide for broader knowledge of dynamics in phytoplankton community composition.

Future directions

- Collection of species specific fluorescence spectra from local species will be completed.
- Field measurements and data processing will be undertaken.



Explaining foreshore vegetation die-off

SP 2018-030

K Trayler, B Huntley

Context

At key locations in the Swan Canning Riverpark there is evidence of riparian decline. At Guildford, widespread die-off of *Eucalyptus rudis* 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.
- Investigate tree health by examining leaf nutrients, pathogen presence, soil moisture, nutrients and mycorrhiza.
- Trial phosphite injection as treatment option for trees impacted in 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

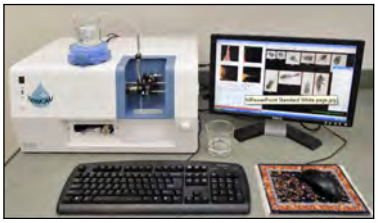
- Remote sensing platforms have been used to develop condition maps showing spatial extent of riparian changes over time (2007-2016).
- On-ground evaluation of tree health has occurred and pathogen assessment undertaken.
- Piezometers have been installed to assess groundwater salinity and water levels.

Management implications

- The application of this approach could be used as an exploratory tool to view the sensitivity of riparian zones under forecast hydrodynamic conditions. This may allow for pre-emptive management approaches to protect existing vegetation or planting of species that are more tolerant of predicted changes.

Future directions

- Piezometer monitoring will continue through the coming summer to evaluate changes in salinity and water level in riparian zones and to determine the river hydrodynamic conditions relative to this.
- Tree injection trials are planned to combat *Phytophthora* in Guildford trees.



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

SP 2018-029

J Cosgrove, K Trayler

Context

The department partners with the Department of Water and Environmental Regulation to conduct weekly water quality monitoring of the Swan Canning Riverpark. Water-borne microscopic algae (microalgae or phytoplankton) are a key component of the monitoring program as they are a foundational part of the food-web and algal blooms can result in significant water quality problems. Microalgae have been counted and characterised by trained taxonomists using microscopes since 1994. Monitoring technologies have evolved since that time, as have the data requirements of the department. 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 estuarine system.

Progress

- The project has encountered numerous technical and methodological issues in what appears to be a poorly documented area of aquatic water quality monitoring. A publication is being drafted to highlight method and reporting improvements that can be made.
- Options for enhancing imaging processing outcomes and improving sample processing speeds are being investigated.

Management implications

- The project will provide system-specific imaging flow cytometry data and an evidence-based local assessment of whether this technology can currently be effectively applied in biological monitoring of the Swan Canning estuarine system.
- If determined to be an effective monitoring tool within the Swan Canning Riverpark, the FlowCAM® would provide new data streams relevant to assessing ecological status. The semi-automated process would also assist in improving data quality by greatly reducing operator bias.

Future directions

- Investigate broadscale changes in the phytoplankton community of the Swan Canning estuarine system and how these are influenced by hydrological and climatic trends.
- Make predictions of future phytoplankton population dynamics, based on identified drivers and modelled predicted hydrological and climatic trends.

Stock enhancement of western school prawn: evaluation recruitment limitation, environment and release strategies

SP 2018-028

K Trayler

Context

The western school prawn (*Metapenaeus dalli*) was the focus of a small commercial and iconic recreational fishery in the Swan-Canning Estuary. However, catches declined significantly through the 1950s and the commercial fishery closed in the mid-1970s. The popularity of the recreational fishery, which is estimated to have involved >50,000 people in the 1980s, also declined. Despite a reduction in fishing effort, stocks failed to recover. Restocking (i.e. releasing cultured individuals to rebuild stocks) was seen as a possible means of increasing the population of *M. dalli*, improve understandings of the species and reinvigorate recreational prawning. Between 2013 and 2016, 4.5 million prawns were grown in aquaculture and released into the Swan Canning Estuary. Research and restocking, which was undertaken collaboratively with Murdoch University and the Australian Centre for Applied Aquaculture Research, was accompanied by a community education and engagement project, known as Prawn Watch, run by the River Guardians Program.

Aims

- Determine the biology and ecology of *M. dalli*, and factors affecting their recruitment.
- Develop release strategies to maximize the survival of hatchery-reared prawns.

Progress

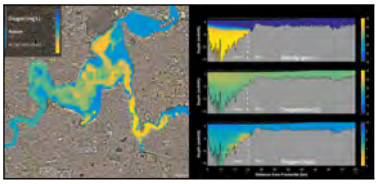
- Monitoring of the school prawn population continued until March 2018 and is now complete.
- A research report summarising findings has been published.
- A supplementary report is in preparation that looks at the spatial and temporal variation of the prawn stock over the 4 years of the breeding period.

Management implications

- This project showed that it was possible to increase the population of prawns in the Riverpark with restocking.
- Monitoring showed storm event and adverse environmental conditions over the summer of 2016/17 had significantly depleted populations of this species in the estuarine environment. Recruitment of this species is limited to within the estuary and therefore recovery of the population, without further restocking, is expected to be slow.
- The current low densities has implications for the sustainable management of this species and fisheries policy may need to change bag limits or consider seasonal closure to protect breeding stock.

Future directions

- There is potential to explore the use of model frameworks to better understand the influence of hydrodynamic conditions on the habitat of the population of school prawns in the Riverpark.



Model frameworks for estuarine reporting

SP 2018-027

K Trayler, J Cosgrove

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 invested considerable resources into 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. Elsewhere similar models have been developed to provide real-time evaluation of estuarine conditions. 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 could greatly enhance existing communications with the community about river conditions and create new opportunities to present 'interpreted' outputs of more relevance to management and outreach. This project aims to explore the capacity of a predictive model framework to rationalise water quality monitoring data and display information in a format that adds value through extension of information.

Aims

- Evaluate optimal water quality data requirements for predictive modelling of estuarine conditions.
- Develop a display portal for model outputs using near real-time data.

Progress

- An analyses of model performance was undertaken against historical data collected at selected sites within the estuary over the period from January 2015 to July 2016. Performance was evaluated both spatially and temporally and error quantified.
- A 'Tracer Model' was applied to identify biogeochemical hotspots that might need additional attention as part of physical or biogechemical monitoring.
- An automation framework of a real-time estuary water quality model for Swan-Canning River was established with automated operation of the model driven by near real-time data and a display portal for model outputs, showing regular visualisations of the SCERM v2 model.

- Data automation frameworks have been further refined to enable import of river flow data. A prototype nutrient import approach has also been developed.
- New bathymetric data, information on transverse water quality dynamics and phytoplankton mobility is being collated and will be included in the next stage of the model extension.
- Several priorities were identified for improving model accuracy/capability. Hotspots of biogeochemical intensity may require additional sampling during some periods to account for variability. The need to capture variation across lateral transects was identified and higher sampling frequency of dissolved oxygen and phytoplankton is required to capture daily variation.
- 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.
- A virtual observatory (beta version) was developed displaying temporal and spatial extent of a range of physico-chemical and water quality parameters across the estuary. This is currently being refined.

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 (eg. total phosphorus, ortho-phosphate and silicon). 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.
- A virtual observatory (beta version) was developed displaying temporal and spatial extent of a range of physico-chemical and water quality parameters across the estuary. This is currently being refined.

Future directions

- It is envisaged that the real-time framework will provide a user friendly portal to view water quality conditions in the waterway via a web-interface.

Dolphin health - toxicogenomics and pathology investigations

SP 2018-023

K Trayler

Context

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 on-going support in post-mortem investigations of individual strandings and unusual mortality events. That work was instrumental in understanding 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 with a university based research project examining toxicogenomics and contaminant exposure in live dolphins.

Aims

- Undertake post-mortem investigations of individual strandings and unusual mortality events in the Riverpark.
- Evaluate if there is any evidence of sub-lethal adverse effects on the immune, endocrine and nervous systems of the dolphins that use the Riverpark in comparison with dolphins in Shark Bay as a ‘control’ population.

Progress

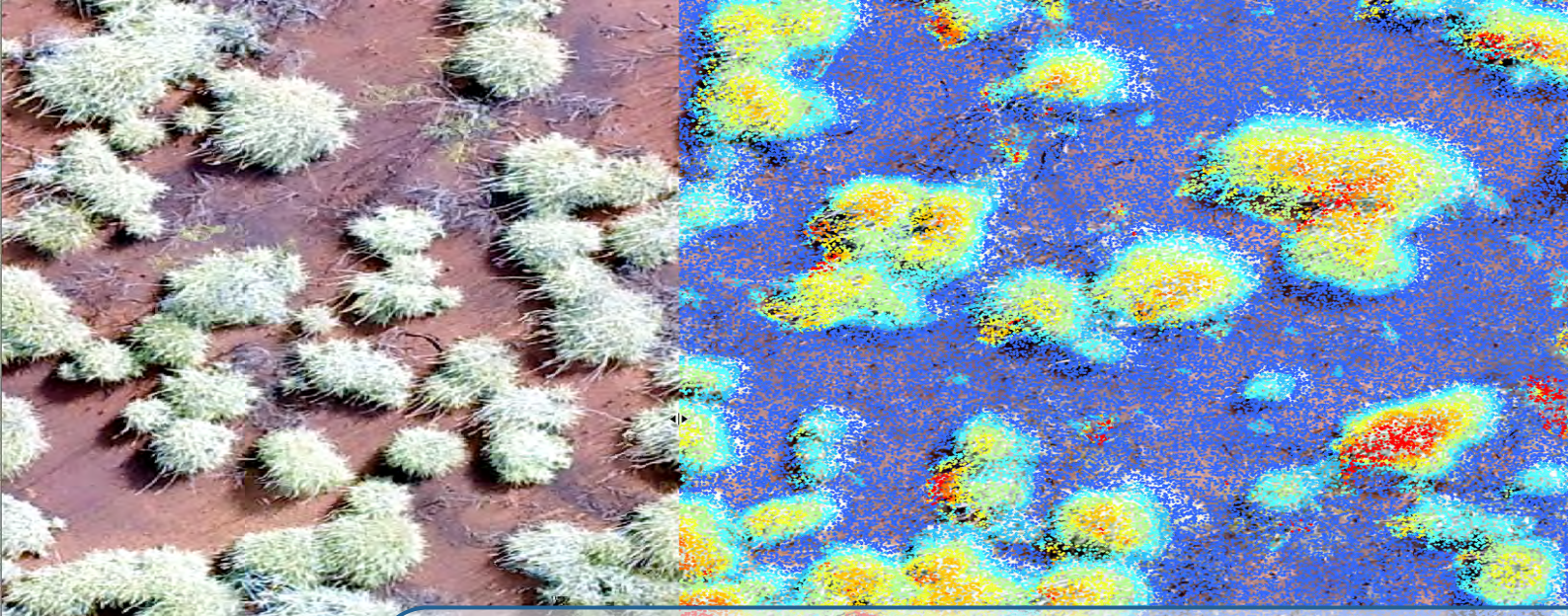
- One deceased dolphin (a calf) was taken from the Riverpark. Gross examination (including measurements and photographs) was undertaken; however, due to post-mortem change necropsy further histopathological examination was not possible. Results of the gross examination revealed the calf to be male which was either still-borne or died shortly after birth. There were no signs of physical trauma to which the death could be attributed.
- Research into the toxicogenomics of the live dolphins has recently competed skin biopsies of the Riverpark dolphin sub-population and those of a control population in the Western Gulf of Shark Bay.
- Laboratory evaluation of skin samples as well as other historic tissue samples are underway.

Management implications

- The Swan Canning Riverpark dolphin sub-population is small and vulnerable to pressures associated with a habitat comprising a major industrial harbour and an urban estuary with high recreational usage and a large agricultural catchment.
- Identifying patterns in injury and disease provides valuable information on pressures affecting the dolphin subpopulation. The information is used in awareness raising and public information events.

Future directions

- Continue dolphin pathology and toxicogenomic investigations.

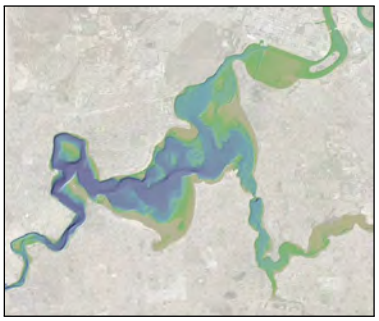


Remote Sensing and Spatial Analysis

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 though 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 datasets developed by science and science collaborations, and migrate this data into Corporate GIS applications and the Spatial Data Library.

Progress

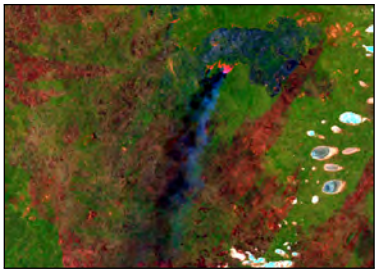
- Updated the Swan and Canning Rivers bathymetry dataset with recently captured depth survey data. Bathymetric spatial products have been made available on corporate systems and have been provided to other government agencies.
- Improved the marine section of the corporate data menu to include Biota (Habitat, Fauna and Fish) and Bathymetry through collaboration with GIS Spatial Library. Collated 19 spatial layers of Kimberley marine data sets generated through Western Australian Marine Science Institute (WAMSI) and other research. These data sets were cleaned to a corporate standard before being added to the corporate data and made accessible to the department. This data was migrated to the Kimberley Region servers and the work to date was presented to Kimberley Marine Park Coordinators in Broome. Kimberley Marine Park Coordinators ranked the remaining 34 data sets identified in this work and 23 data sets were identified as high to medium priority to be migrated to corporate data in the near future.
- Facilitated improvement in the definition of the coastline boundary to the mean high water mark for the North Kimberley Marine Park - Balanggara Indigenous Land Use Agreement (ILUA) section between Cape Dussejour (Cambridge Gulf) and Curran Point (Drysdale River).
- Download and data correction processes have been scripted in Python and R to allow batch processing. Scripts and functions are under constant development as download sources change and adapt to new satellites and storage infrastructure.
- Processes attributed and migrated into the corporate GIS, two aerial photography surveys that captured marine turtle rookery habitat (beaches) across the Kimberley regions as part of WAMSI Project node 1.2.2.

Management implications

- The updated bathymetry is being used for monitoring and as an input into hydrodynamic elements of the Swan Canning Estuary Response Model.
- Appropriate access and curation of WAMSI data means that Kimberley Marine Park coordinators are now able to use this data and knowledge to support management and monitoring for existing Kimberley Marine Parks and the current marine park planning process for the proposed Buccaneer Archipelago.
- Greater accuracy in defining the coastline for the North Kimberley Marine Park is integral to monitoring mangrove and other conservation assets in the marine park, and to provide a good basis for marine park mapping and operational management.

Future directions

- Continue to update satellite imagery LIDAR and DEM catalogues.
- Maintain scripts and functions to download data sources for satellite imagery and migration to storage infrastructure with Office of Information Management and Pawsey Supercomputing Centre.
- Update and document new and ongoing fundamental data sets.
- Identify geographical or temporal gaps in aerial photography or high resolution satellite imagery data and lodge requests with the *Capture WA* program. Use *Capture WA* to lodge requests for LIDAR or bathymetry data required for departmental purposes.



Remote sensing and spatial analysis for fire management

CF 2018-074

J Chapman, B Huntley, G Pitt, P Rampant, K Zdunic

Context

The department's fire management, monitoring and reporting functions require knowledge of fire events that is 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 which 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 bush fire. 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. 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 post-burn 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

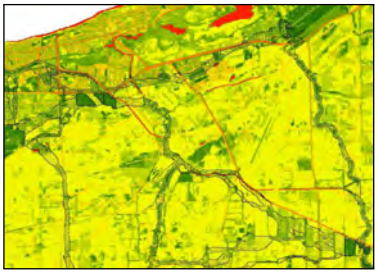
- Continued development of remote piloted aircraft obtained spinifex cover field data and Landsat imagery application for input to spinifex fire behaviour models. Results were presented at UAS4Enviro2018 conference.
- Fire scar information for the Pilbara region and Kanyirninpa Jukurrpa was supplied on a monthly and annual basis to inform and report on prescribed burning and fire suppression activities in the Western Desert.
- Refinement of methodology for operational use of thermal camera to detect hotspots for burn security.
- Supported Fire Management Services Branch with data to inform fire recovery, fire chronology and new satellite technology/availability.
- Fire risk model for Swan Region was updated.
- Determined traditional and contemporary fire patterns in the Great Victoria Desert.

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.
- 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.
- Through the availability and use of fire scar information in the Pilbara, the application and requirement for fire scar information has grown. 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.
- Security of burns is improved by the delivery of thermal imagery hotspots to on-ground staff.
- Updates to the Swan Region Fire Risk Model informs prescribed burn planning.

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.



Spatial analysis and modelling

SP 2018-073

J Kinloch, K Zdunic, 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.

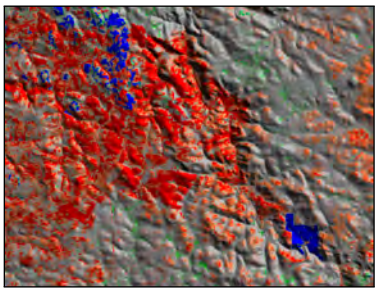
Progress
- Satellite tracking of horses for the Fortescue Marsh Feral Herbivore Program continued. Undertook spatial analysis of animal movement and determined home range statistics.
- Developed a risk assessment framework for illegal sandalwood harvesting and worked with wildlife enforcement staff to identify data requirements for the parameterisation of the model.
- Completed the 2017 report on the extent of the Nature Conservation Estate (IUCN I-IV conservation reserves and IUCN IV conservation covenants), other departmental managed lands and Indigenous Protected Areas in each of the IBRA sub-regions.
- 2017 Statewide and 2017 South West Vegetation Statistics reports were completed and published on DataWA. For the South West report an expanded internal departmental report was completed that included extent of vegetation complexes remaining on freehold and crown land not managed by the department.
- One-off vegetation complexes analyses were completed for the Perth and Peel Regions to inform decision making for areas for retention across these two regions.

Management implications

- The feral horse spatial data sets and analysis have provided land managers with information on the movement of horses on Fortescue Marsh and surrounds so that effective management strategies can be formulated to minimise feral herbivore impact on the Marsh.
- Development of State Government sandalwood spatial data sets has provided departmental Wildlife Officers with access to this data and has facilitated the capture of data relating to legal and illegal harvesting when undertaking patrols.
- The vegetation statistics analyses provide a single-point of truth and publicly available reports provide up-to-date CAR statistics, required by government and non-government organisations for reporting and to inform decision making.

Future directions

- Explore utility of Urban Monitor imagery and height data to assess vegetation aspects of extent, structure and status for threatened ecological communities.
- Produce 2018 Statewide and 2018 South West Vegetation Statistics reports.
- Provide spatial analysis support for analysis of Pilbara mammals.
- Model the habitat of *Aluta quadrata* in the Pilbara.
- Produce terrestrial lands report for 2018.



Remote sensing monitoring

SP 2018-072

J Chapman, B Huntley, J Kinloch, 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 developing repeatable and consistent source imagery and 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 projects and research development at a range of temporal and spatial scales using remote sensing technologies which include satellite imagery, digital cameras, remotely piloted aircraft and LIDAR data.

Progress

- Carried out Dirk Hartog Island field trip and analysis including assessments of vegetation change, proposed airstrip inundation and exclusion plot locations.
- Finalised field data capture of Anketell Road revegetation site.
- Delivered inputs into the Forest Management Plan covering the following KPIs – KPI 1: Whole of Forest Condition, KPI 2: Threatened and Priority Ecological Communities, KPI3: Ramsar and nationally listed wetlands and KPI 8: Resilient and healthy forest ecosystems.

- Developed a system to assess plantation stocking rates for Forest Management Branch.
- Provided analyses updates to the South West Wetland Monitoring Program.
- Completed vegetation cover change assessment over the Yarraloola pastoral lease for Rio Tinto.
- Continued the Millstream Chichester National Park riparian vegetation monitoring.
- Provided input to the Land Monitor Project to progress rangeland vegetation monitoring.

Management implications

- The inputs developed for the Forest Management Plan reporting provide management with a broad range of statistics that can be used to assess forest condition and report on the success and utility of forest management practices.
- Field validation at the Anketell Road site can be used demonstrate the effectiveness of detail provided by new satellite technology in environmental monitoring.
- Stocking rate assessments for Forest Management Branch provide a cost effective and comprehensive process to assess stocking rates in south west plantations.
- Planning for new infrastructure on Dirk Hartog Island is improved by analysis of inundation history of potential airstrip sites.

Future directions

- Continue to develop the stocking rate assessment for Forest Management Branch into a production system.
- Improve the connection with field information obtained by the regions and remote sensing analysis for Forest Management Plan reporting.
- Collaborate with Kings Park Science and Murdoch University on 2010/11 drought effects and woodland monitoring.
- Complete Kwinana freeway foreshore vegetation change assessment for Rivers and Estuaries Branch.
- Explore reserve monitoring options with Environmental Management Branch.
- Continue to explore and develop cloud processing options with Geoscience Australia and Google Earth Engine.

Species and Communities

Program Leader: Ken Atkins 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, H Bucktin, F Felton

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. Maintaining wetland inventory across the State allows the department to provide accurate technical and scientific advice on 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

- Information sheets and mapping reviews for three Ramsar sites are in various stages of preparation.
- In response to a request from the Australian Government, preliminary assessments to determine the condition of two Ramsar sites have been completed (Muir-Byenup System and Lake Gore) and a third assessment (Vasse-Wonnerup System) is underway.
- Vegetation community mapping was completed for mound spring communities in the northern and east Kimberley.
- 11 requests to modify the *Geomorphic Wetlands Swan Coastal Plain* dataset were processed.
- Technical advice was provided to the Department of Water and Environmental Regulation for 17 clearing applications.
- Technical advice was provided to departmental staff, other state and commonwealth agencies, land owners and their consultants for 42 land use planning issues.
- Weed control, fencing and revegetation were undertaken on a number of properties through the Healthy Wetland Habitats program.
- The Healthy Wetland Habitats program currently has 16 active participants and three new voluntary management agreements have been signed.
- Eight site visits were undertaken, and staff identified the presence of the rare Carter's freshwater mussel (*Westralunio cateri*) at five sites across two properties. Weed control is being undertaken in the habitat of the mussel.

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.
- 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.

Future directions

- Provide input to the design and development of a monitoring and evaluation program for Ramsar sites across Western Australia.
- Collection and uploading of data into a corporate database with facilities for public query.

Ecological communities conservation and recovery

CF 2018-066

V English, W Hudleston, J Pryde

Context

The ecological communities team collates and manages biodiversity information, and provides a range of science based support for the management, protection and recovery of Threatened Ecological Communities (TEC) and Priority Ecological Communities (PEC). Maintaining and managing the TEC data base allows 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 change of status, ensures that the most recent ecological information is available to stakeholders. The department facilitates the Threatened Ecological Communities Scientific Committee and coordinates recovery programs, including developing interim recovery plans and supporting recovery teams, to guide conservation activities in 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 TECs and PECs conservation values for development and vegetation clearing proposals in accordance with relevant policy and legislation.
- Undertake on ground assessment and provide conservation advice in regard to 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 of the TECSC.

Progress

- The Minister approved one change to the conservation status of a TEC during the year.
- At 30 June 2018, there were 65 extant ecological communities listed by the department as TECs (20 critically endangered, 17 endangered and 28 vulnerable) and four listed as 'presumed destroyed'. Another 391 ecological communities are on the PEC list.
- An interim recovery plan was approved for one TEC and four interim recovery plans were drafted.
- 375 data search requests for TECs and PECs were processed for a range of stakeholders including departmental staff, other government departments, consultants, commercial interests and community groups. Specialist TEC advice was also provided in conjunction with a number of these search requests.
- New occurrence information was added as well as edits to existing spatial information on the TEC and PEC data base for 42 occurrences distributed across the State.
- On ground survey and monitoring was undertaken for 27 occurrences of TECs and PECs throughout the State.
- Support and specialist input was provided, and where possible meetings attended, for the Threatened Flora and Communities Recovery Teams representing the Swan and Warren Regions, and the Albany, Esperance, Central Wheatbelt and Geraldton Districts.
- Environmental impact assessment advice was provided in relation to 110 clearing permit applications, land use planning advice, mining and development proposals. Specialist advice was provided to the Commonwealth Department of the Environment and Energy on the listing of TECs and input into the Approved Conservation Advice under the *EPBC Act*.
- One meeting of the TECSC assessed the nominations for listing three ecological communities.
- Information and expert advice was provided for a case in the Supreme Court of Western Australia involving an occurrence of a TEC.

Management implications

- Enhanced data sets for TECs and PECs facilitate improved assessment and conservation.
- Updates to the TEC and PEC data base assists in resolving the status of ecological communities and provides improved information for land use planning and management.
- Management advice assists the department and other land managers to maintain the conservation status of TECs.
- Provision of input into the environmental impact assessment and land use planning processes maximises the potential for positive conservation outcomes.

Future directions

- Continue to maintain the TEC and PEC data base.
- Continue to provide data and advice for the protection, conservation and management of TECs and PECs.
- Commence re-assessment of existing TECs against the Ministerial Guidelines, using the IUCN Red List of Ecosystems criteria and prepare nominations where the threat category changes under these criteria.
- Prepare nominations for additional TECs using the Ministerial Guidelines.
- Finalise the four draft interim recovery plans.

Off-reserve conservation

CF 2018-061

K Atkins, N Casson, 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 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

- Increase community awareness of biodiversity conservation and promote the department's biodiversity conservation activities through community and land manager consultation.
- Integrate science knowledge into technical biodiversity management advice.
- Improved conservation management on lands not managed primarily for nature conservation.
- Enhance the conservation estate through nature conservation covenants.

Progress

- Twenty five landowners applied for registration with Land for Wildlife during 2017/18, and a total of 1,975 properties are currently registered supporting 286,873 ha of bushland managed for conservation.
- Thirteen property assessments were undertaken for Land for Wildlife by NRM partners, and 13 by the departmental coordinator. Twenty three properties were added to the program and three were deemed unsuitable.
- New information material for Land for Wildlife has been produced with co-badging between the department and NRM WA.
- An edition of the newsletter, *Western Wildlife*, was produced and mailed to all Land for Wildlife members. This publication is being transitioned to a digital format.
- A presentation on the Land for Wildlife program was given to the Threatened Species Forum in Geraldton.
- Seventeen new nature conservation covenants were registered covering 2,172 ha. Nature conservation covenants have been established on a total of 313 land titles, covering 22,726 ha, including habitat for threatened species and ecological communities, a Ramsar wetland and registered Aboriginal heritage sites.
- Advice was provided to land owners, local government and departmental planning staff on land use planning matters relating to covenants.
- Staff provided information on nature conservation covenants at a field day relating to natural land management.
- Four meetings of the Roadside Conservation Committee were supported.
- Training in roadside management was provided to five local governments, and a guidance document about how to manage roadside vegetation and minimise impacts of road works was prepared.
- Advice was provided to members of the community and road managers regarding roadside management issues.

- Work was undertaken with local government on rationalising road design requirements for increasing road standard demands, and in reviewing the AusRoads standards.

Management implications

- Off-reserve conservation plays an important role in achieving the conservation of the State's biodiversity. For example, 68% of threatened flora subpopulations (at 2017) occur on land not managed by the department, and 23% 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.
- Off-reserve lands are also often integrated with department-managed land, either by being adjacent to, or by providing linkages. Effective management of these lands, and the integration of management practices with those of the department, facilitate more effective management of the conservation estate to achieve biodiversity conservation outcomes.

Future directions

- Publish a technical guide to roadside pruning.
- Publish one electronic edition of the *Western Wildlife* newsletter.
- Develop a process for using spatial analysis to identify freehold land adjacent to the conservation estate for potential covenant sites.
- Establish all conditional covenants within the required planning approvals time frame.

Flora conservation and recovery

CF 2018-057

M Smith, T Llorens, A Jones, J Donaldson, K Griffiths, R Luu, S Martin, K Valentine

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 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 permits to take DRF 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 threatened 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

- Two hundred and three permits to take DRF were issued. Of these, 73 were issued for herbarium specimen collections for identification purposes (22 internal and 51 external), 43 were issued for scientific/research purposes (23 internal and 20 external) and 90 were issued for land management/operational purposes (45 internal and 45 external).
- Five hundred and eighty four new records were added to the TPFL database, of which 154 were records of new populations.
- A review of translocation data was undertaken, resulting in 40 threatened flora translocated populations being added to the TPFL database.
- Three hundred and seventy five data search requests for threatened and priority flora were processed (24 internal, 83 other government departments, 227 consultants, and 41 other organisations).
- Conservation status assessments resulted in 87 additions to the priority flora list, as well as the re-listing of two taxa, and de-listing of 21 taxa after survey and taxonomic review clarified their conservation status.
- Five species had conservation status reviews undertaken and presented to the TSSC. This included one nomination for an addition to the threatened species list and four conservation status assessments of threatened flora for changes in category and/or criteria.
- Administered changes to the Rare Flora Notice published January 2018 included: eight additions and four deletions to the threatened flora list; one addition and one deletion to the list of presumed extinct flora; assignment to a higher threatened category for seven species; down grading of three species to a lower category of threat; criteria change for nine species; and two name changes.
- Conservation status was reviewed for 17 taxa described in draft *Nuytsia* manuscripts.
- A recovery plan was prepared for one species, and interim recovery plans were drafted for another 10 species of threatened flora.
- Translocation proposals were approved for seven internal and six external projects.
- The management plan for the commercial harvesting of protected flora was updated, and the new plan was approved under the *EPBC Act* as an approved Wildlife Trade Management program.
- Impact assessment advice was provided in relation to 102 clearing permit applications, 28 other mining or development projects (42 separate advice requests) and four land use planning proposals with the potential to affect threatened and priority flora.
- The 2017 Flora Conservation Course was delivered to 19 staff.
- Support was provided for the meeting of Threatened Flora Recovery Teams representing the South Coast, Goldfields, Swan and Warren Regions, and the Albany, Esperance, Central Wheatbelt and Geraldton Districts.
- Volunteers in the Swan and Warren regions and Albany and Geraldton districts assisted in conducting surveys for many threatened 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 22 threatened and priority orchid species, with 60 populations monitored and 11 new populations discovered.
- Provided information and advice to the Department of the Environment and Energy to support threatened species listing and recovery plan decisions for 79 flora taxa, as well as a comprehensive review of federal recovery plans and conservation advice for three species listed under the *EPBC Act*.
- Representation continued on the national working group for implementing the MoU on a Common Assessment Method for assessing threatened species. Fifty one species of flora had their status aligned with the *EPBC Act* through this process.

Management implications

- Enhanced data sets and lists for threatened and priority flora facilitate improved assessment and conservation.

- Updates to the threatened and priority flora data base 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 assess the conservation status of flora and prepare six flora recovery plans.
- Make available the Threatened Flora Management Course for departmental staff.
- Transition to the new threatened species database and test the database for operational use, and train regional staff in the use of the new database.
- Revise threatened flora operational procedures as required under the *Biodiversity Conservation Act*.

Fauna conservation and recovery

CF 2018-040

M Page, J Renwick, A Mutton, G Anderson

Context

The fauna conservation team collates and manages biodiversity information and provides a range of science based support for fauna conservation and recovery. Maintaining and managing the Threatened and Priority fauna database 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 and coordinates recovery programs, including developing interim recovery plans and supporting recovery teams, to guide translocations and conservation activities involving threatened and priority fauna. The team facilitates the department's Animal Ethics Committee (AEC) to manage requirements for ethics considerations in research 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 distribution, conservation status and recovery 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 prepare nominations for the consideration of the TSSC.
- Inform policy and strategic direction relating to fauna, including animal welfare.
- Provide technical advice on assessment of environmental impacts on fauna for development and vegetation clearing proposals, and licence applications to take fauna for scientific, education, public and relocation 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*, its *Licence to use animals for scientific purposes*, and the *Australian Code for the Care and Use of Animals for Scientific Purposes*.

Progress

- A total of 381 fauna species are declared to be rare, likely to become extinct or otherwise in need of special protection under the *Wildlife Conservation Act 1950.* As at 30 June 2018, there were 249 threatened fauna species (52 listed as critically endangered, 56 as endangered and 141 as vulnerable), 23 presumed extinct, seven conservation dependent, seven other specially protected and 95 migratory bird species that are protected under an international agreement, and 214 species on the department's priority fauna list.
- Ten fauna nominations were considered by the TSSC, resulting in two additions (Lake Goorly shield-backed trapdoor spider and ornate shield-backed trapdoor spider) and one deletion (Airlie Island *Ctenotus*) from the list of threatened fauna, one species moved to a higher category of threat (shield-backed trapdoor spider, *Idiosoma nigrum*) and one species moved to a lower category of threat (*Banksia brownii* plant-louse), and three changes to listing criteria only (Margaret River hairy marron, Mesa A *Paradraculoides* and sunset frog). Three additions to, and 11 deletions from, the list of migratory birds were incurred, and 37 nomenclature changes were implemented.
- A total of 15 nominations were forwarded to the Australian Government for amendment of the threatened species lists under the*EPBC Act*, and six additions to the *EPBC Act* occurred during the year.
- 13,734 records of sightings, captures or evidence of threatened and priority fauna were added to the Threatened and Priority Fauna database or the Fauna Survey Returns System. A total 63,695 records are in the Threatened and Priority Fauna database.
- Two hundred and thirty nine threatened and priority fauna data searches and extract requests were performed and numerous responses were provided to fauna enquiries.
- Two hundred and fifty two applications were assessed for licences to take fauna for scientific, education, public and relocation purposes under the *Wildlife Conservation Regulations 1970* (Regulation 15 or 17).
- Fifty six 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.
- A draft recovery plan was completed for the Australasian bittern (*Botaurus poiciloptilus*) and an interim recovery plan was completed and approved for the Abrolhos painted button-quail (*Turnix varius scintillans*). The numbat (*Myrmecobius fasciatus*) and western ringtail possum (*Pseudocheirus occidentalis*) recovery plans were endorsed and adopted as national recovery plans under the *EPBC Act*.
- Support was provided to 17 fauna recovery teams that were active during 2017-18.
- Nine translocation proposals for introduction, reintroduction or restocking purposes were approved for: banded hare-wallaby, chuditch, dibbler, greater stick-nest rat, malleefowl, rufous hare-wallaby, Shark Bay mouse, and western barred bandicoot.
- Five amendments were granted for previously approved translocation proposals for: dibbler, Gilbert's potoroo, noisy scrub-bird, red-tailed phascogale, and western swamp tortoise.
- Eighteen translocation releases occurred for: banded hare-wallaby, Barrow Island boodie, bilby, black-flanked rock-wallaby, chuditch, dibbler, Gilbert's potoroo, noisy scrub-bird, numbat, orange-bellied frog, red-tailed phascogale, rufous hare-wallaby, Shark Bay mouse, tammar wallaby, western barred bandicoot, western swamp tortoise, and white-bellied frog.
- The AEC met seven times, conducted a total of 306 assessments, approved 14 new projects and approved the renewal of 16 projects. There were 131 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. Assessments included all applications that came before the committee for new projects, renewals, amendments, adverse events, and project annual reports.

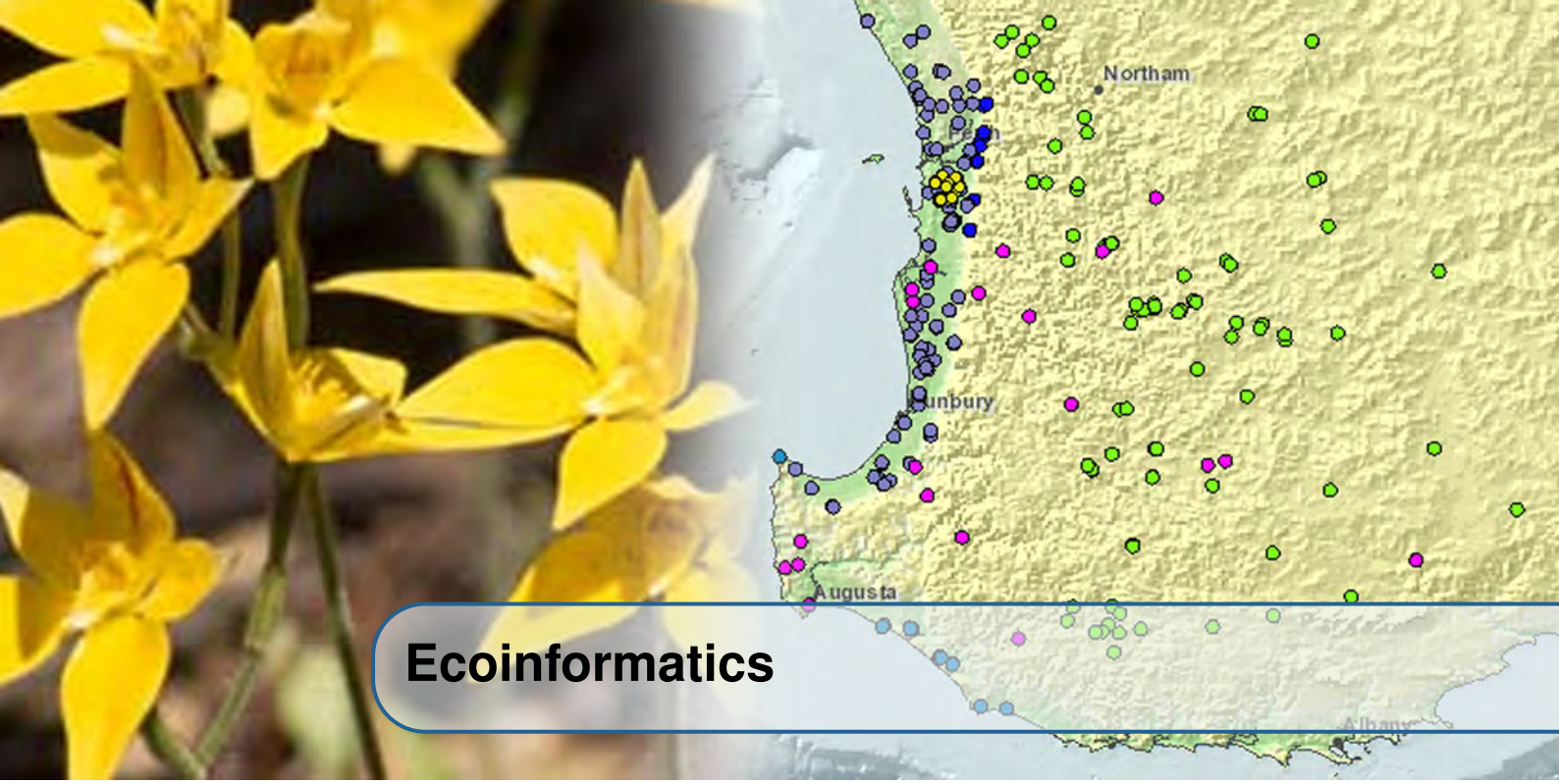
Management implications

- Enhanced data sets and lists for threatened and priority fauna facilitate improved assessment and conservation.
- Updates to the threatened fauna data base assists in resolving the status of fauna and provides improved information for land use planning and management.
- Management advice, and assessment of applications for licences to take or for the translocation of threatened fauna, assists the department and other land managers to maintain the conservation status of threatened and priority fauna.

- Departmental animal welfare requirements are maintained.
- Industry management programs and threatened fauna 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 fauna in an efficient manner.
- Transition to the new threatened species database, and test the new system to ensure it operates effectively.
- Prepare fauna conservation advice within requested time frames.
- Prepare one new threatened fauna recovery plan.
- Develop guidelines for bilby translocation.
- Facilitate Commonwealth endorsement of the new kangaroo management program.
- Prepare guidelines and procedures for the implementation of the *Biodiversity Conservation Act*.



Ecoinformatics

Program Leader: Paul Gioia 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

P Gioia, F Mayer

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 now 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 20 major projects comprising 160 data sets and 750,000 records within the repository. Legacy data sets are being migrated to the new system, including important historical regional surveys, island flora and fauna, resource condition monitoring data, Carnaby's cockatoo, *Banksia* woodlands, Pilbara threatened fauna, Threatened Flora Seed Centre collections, many surveys from individual scientists, and a wide range of other datasets.
- The NSW Office of Environment and Heritage (OEH) commenced a collaborative project with the department to assess the feasibility of using BioSys within their biodiversity data workflow. BioSys was created as an open source project, allowing organisations such as OEH to use and extend the existing code base. To that end, OEH has implemented a pilot project focusing on koalas, an iconic species of special interest within NSW. Primary outputs include an offline mobile data collection tool that synchronises directly with BioSys, and major enhancements to BioSys itself.

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

- OEH project success will be evaluated in late 2018. All enhancements to BioSys are available to the department and the public at no cost, including the data collection tool. With minor additional expenditure, the mobile data capture solution can be customised for use within the department. A variety of applications are under consideration.
- Other State jurisdictions are evaluating the outcomes of this project. Further collaborations and potential investment will be explored to extend the capacity of BioSys to managing biodiversity data.

Provision of authoritative names of Western Australian taxa

CF 2011-108

P Gioia

Context

The department, academia and the community rely on authoritative species names to manage species databases. Without authoritative names, the ability to provide and integrate information is substantially impeded. WACensus, a database system, is the primary mechanism for managing those names. WACensus captures both current names and synonymies and information is disseminated widely throughout Western Australia. The department assumes a leadership role in providing authoritative names to assist in bio-inventory of both plants and animals, and the delivery of high quality information to a range of clients. There is a need to provide a standard mechanism for collection and management of plant species information. Max is a species database management system that substantially improves data accuracy through facilitating the correct use of names, and promotes a standard database design integrated with WAHerb, the Western Australian Herbarium's specimen database.

Aims

- Provide accurate and timely information on the names of Western Australian taxa to assist in management of species databases within the department and the wider community.
- Maintain updated species databases and provide facilities for entering specimen label information.

Progress

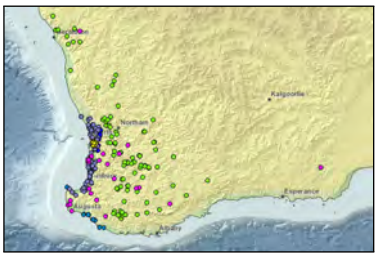
- WACensus data is now available through web services, providing both internal and public access to authoritative names data, and facilitating system integration.
- Annual statistics are now automatically generated and incorporated into *FloraBase*.
- Minor bugs have been fixed and enhancements implemented.
- Max continues to be maintained and enhanced to provide alignment with WAHerb, the most recent, authoritative species name information, and support for over 250 registered users within and external to the department.

Management implications

- The development of any database in the department that involves plant species names needs to be linked directly to WACensus data so that nomenclatural changes can be taken into account.
- Max provides a standard mechanism for entering specimen data, as well as the capacity to check species names against the most authoritative source, thus enabling better integration of floristic information.

Future directions

- WACensus is currently architected in a legacy environment. Development has commenced on the migration of WACensus to a modern environment consistent with other departmental systems. This will substantially improve integration with other recently developed core systems such as those managed by Wildlife Licensing and Threatened Species and Communities.



Online GIS biodiversity mapping (*NatureMap*)

CF 2011-106

P Gioia

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

- A new Western Deserts theme (facilitated and funded by Rangelands NRM) is now available, based on biodiversity surveys and monitoring programs undertaken in the Western Desert by the traditional owners.
- Major enhancements were made to the user interface, including satellite imagery base maps, improved querying, and management of sensitive data.

- A wide variety of additional data sets were added, including Pilbara riparian flora, Priority Flora, monitoring data from Western Shield, historic Dell bird records, Carnaby's Cockatoo observations, Goldfields fauna observations, and various public data submissions
- Occurrence records now total 5.3 million, an increase of over 200,000 records.
- An additional 215 new registrations were recorded, bringing the total from 2,579, a 9% increase.

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*, including the Pilbara Biological Survey.
- Improved integration with BioSys, the Western Australian Biological Survey Database

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	$165,000	J Dunlop, K Morris, S van Leeuwen
Atlas Iron, Main Roads Western Australia	Ecology and management of the Pilbara olive python	$25,000	D Pearson, S van Leeuwen, K Morris
Atlas Iron, Roy Hill	Investigating the interactions between feral predators in the Pilbara	$450,000	K Morris, S van Leeuwen
Atlas Iron	Ecology and management of the Pilbara leaf-nosed bat	$70,000	S van Leeuwen, K Morris
Australian Biological Resources Study, Queensland Herbarium, Northern Territory Herbarium, University of the Western Cape (South Africa)	Towards an eFlora treatment of *Tephrosia* (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 offshore movement of flatback turtle hatchlings and the effects of anthropogenic light	$400,000	S Whiting
Australian Institute of Marine Science	Potential anthropogenic impacts on Ningaloo whale sharks as determined through the tourism electronic monitoring system and scarring patterns	Nil	H Raudino, K Waples
Australian Nuclear Science and Technology Organisation (ANSTO)	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, CSIRO, Alcoa	Genomics for climate adaptation in *Eucalyptus* foundation species	$375,000	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, D Coates
Australian Research Council, Charles Darwin University, Save the Gouldian Fund, Ballanggarra 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, Karara Mining Ltd, The University of Western Australia	Managing genetic diversity and evolutionary processes in foundation species for landscape restoration in the midwest of Western Australia	$527,000	D Coates, M Byrne, M Millar
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
Australian Research Council, Murdoch University	Optimising fire regimes for fire risk and conservation outcomes in *Banksia* woodlands in the Perth area	$455,000	B Miller, K Ruthrof
Australian Research Council, Murdoch University	The ecology of parasite transmission	$150,000	A Wayne, K Morris
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

Partners	Project Title	External Funding	Departmental Involvement
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
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 (NSW), Department of Environment, Water and Natural Resources (SA), Smithsonian Institute (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 (ANSTO)	Hydrogeochemistry of Walyarta Springs	$120,000	J Rutherford
BHP	Identification botanist position at the Western Australian Herbarium	$105,000	J Huisman, S Dillon
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, M Barrett
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
Birdlife WA	Shorebirds 2020 - capacity and information exchange	$7,500	K Trayler
Bushfire and Natural Hazards CRC	Bushfire and Natural Hazards CRC	Nil	L McCaw
CSIRO, Australian SuperSite Network, Terrestrial Ecosystem Research Network, National Research Infrastructure for Australia	Great Western Woodlands SuperSite	Nil	S van Leeuwen

Partners	Project Title	External Funding	Departmental Involvement
CSIRO, National Environmental Science Program - Marine Biodiversity Hub	Dugong population and habitat survey - Shark Bay and Ningaloo	$123,622	H Raudino
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
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 (*Pezoporus occidentalis*) 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 *Passiflora foetida* 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
CSIRO	Pilbara Marine Conservation Program	Nil	T Holmes, K Waples, A Kendrick, G Shedrawi
CSR Gyprock	Wetland flora and fauna of the Jurien coast	$138,000	A Pinder, M Lyons, K Quinlan, R Coppen
Caring for our Country	Identifying threats to marine biodiversity of the Ningaloo World Heritage Area: deeper water fish community surveys within the Ningaloo Marine Park	$65,000	T Holmes
Central Desert Native Title Services	Fire scar mapping - Kiwirrkurra Indigenous Protected Area	$1,600	B Huntley, K Zdunic
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

Partners	Project Title	External Funding	Departmental Involvement
Cliffs Asia Pacific Iron Ore Pty Ltd, The University of Western Australia	Integrated conservation and translocation of the threatened banded ironstone species *Tetratheca erubescens* (Elaeocarpaceae)	$997,000	D Merritt, S Krauss, B Miller, J Stevens, W Lewandrowski, C Elliott
Cooperative Research Centre for Honey Bee Products, University of Adelaide, Dijilarup Manuka Pty Ltd, Spring Gully Foods	Understanding the genetic diversity of native *Leptospermum* species for high value honey products	$416,100	M Byrne, R Binks
Curtin University, Department of Primary Industries and Regional Development	Cross and long-shore variations in reef fish assemblage structure and implications for biodiversity management	Nil	T Holmes
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	J Stevens, S Krauss, D Merritt
Curtin University, The University of Western Australia	The energetic basis to seed longevity and storage	$336,000	D Merritt
Curtin University	Using historical aerial imagery to quantify the spatial and temporal response of coral reefs to disturbance within Coral Bay, Ningaloo	Nil	G Shedrawi
Dambimangari Wanjina-Wunggurr Aboriginal Corporation, Bardi and Jawi Niimidiman Aboriginal Corporation	Benthic biodiversity surveys of intertidal *wooddooroo* (coral reefs) in the Lalang-garram, North Kimberley and proposed Buccaneer marine parks	$214,500	T Holmes, W Robbins, 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	Dr L Guzzomi, D Merritt
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	J Rutherford, A Pinder, B Huntley, G McGrath
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, Department of Water and Environmental Regulations, Kimberley Land Council, Nyamba Buru Yawuru Ltd, Yamatji Marlpa Aboriginal Corporation, Karajarri Aboriginal Corporation, Nyangumarta Warram Aboriginal Corporation.	La Grange Irrigated Agriculture Project area bilby and conservation significant flora surveys	$600,000	M Byrne, S van Leeuwen, M Dziminski, M Lyons, A Markey

Partners	Project Title	External Funding	Departmental Involvement
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	Statewide vegetation statistics and south-west vegetation complex statistics (CAR analyses)	$15,000	J Kinloch, G Pitt
Department of the Environment and Energy - Environmental Resources Information Network, Terrestrial Ecosystem Research Network	Essential Environmental Measures	Nil	S van Leeuwen, P Gioia
Department of the Environment and Energy - Threatened Species Commissioner, Rangelands NRM Western Austrlia	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	$136,000	S van Leeuwen, L Gibson, M Cowan, N Gibson
Digital Earth Australia, Geoscience Australia, Earth Observation Governmental Network	Remote sensing based marine monitoring framework development with Geoscience Australia	$14,000	K Murray, K Zdunic, B Huntley, G Pitt, W Robbins, K Bancroft
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 flatback turtles for science, conservation and education	Nil	S Fossette-Halot, S Whiting, T Tucker
Fortescue Metals Group, Millennium Minerals, Roy Hill	Ecology and management of the bilby in the Pilbara	$205,000	M Dziminski, K Morris, F Carpenter, S van Leeuwen
Fortescue Metals Group	Vegetation map reconciliation and compilation for the Hamersley and Fortescue subregions in the Pilbara	Nil	S van Leeuwen, B Bayliss
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, M Rule
Great Victoria Desert Biodiversity Trust	Traditional and contemporary fire patterns in the Great Victoria Desert	$7,600	K Zdunic, N Burrows, J Chapman, R Van Dongen
Hanson Construction Materials	Restoring *Banksia* Woodland communities after mining	$25,000 pa	J Stevens, W Lewandrowski, A Ritchie
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	G Shedrawi, S Field, S Wilson
James Cook University	Human impacts on coral reef communities	Nil	S Wilson

Partners	Project Title	External Funding	Departmental Involvement
James Cook University	Establishing baselines and assessing vulnerability of commercially harvested corals across northern Australia	$150,000	M Moustaka, S Wilson
Kanyirninpa Jukurrpa	Western Desert Land Cover Classification Pilot Project	$17,000	J Chapman, K Zdunic
Landgate	Western Australian State Government Data Catalogue	$12,000	F Mayer
Macquarie University	Investigating the potential for interactive communication between geographically isolated groups of female Asian elephants (*Elephas maximus*) using electronic media	Nil	P Mawson
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 (*Macrotis lagotis*) on the Dampier Peninsula, Kimberley	$600,000	M Dziminski, F Carpenter, K Morris, S van Leeuwen
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 Cochrane, D Coates
Murdoch University - Centre for Sustainable Aquatic Ecosystems	Baseline microbial surveys in Swan Canning	Nil	K Trayler
Murdoch University, Curtin University	Evidence based management of foxes adjacent to turtle beaches in Western Australia	$300,000	S Whiting
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	S van Leeuwen, M Dziminski, F Carpenter
National Environmental Science Program - Threatened Species Recovery Hub	Project 4.3: Improving threatened plant reintroduction success and species recovery	$699,000	D Coates, L Monks, R Dillon, M Byrne
National Science Foundation (USA)	Systematics and biogeography of the Inocybaceae	$19,000	N Bougher

Partners	Project Title	External Funding	Departmental Involvement
Net Conservation Benefits, CSIRO	Molecular characterisation of stinking passionflower (*Passiflora foetida*)	$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	P Gioia
Parks Australia and other Christmas Island land management organisations	Christmas Island cat eradication	$250,000	D Algar, N Hamilton
Quadrant Energy	Coral recruitment monitoring in Ningaloo Marine Park	$42,000	G Shedrawi
Rangelands NRM Western Australia, Pilbara Corridors, Greening Australia	Fortescue Catchment Project - Biodiversity assets and landscape-scale management of the Fortescue River catchment	Nil	S van Leeuwen, K Morris
Rio Tinto, BHP	Seed collection zones for the Pilbara	Nil	M Byrne, R Binks, S van Leeuwen, D Coates
Rio Tinto	Satellite imagery assessment of the fire regime on Yarraloola and Red Hill Stations, Pilbara	$4000	J Chapman, K Zdunic
Rio Tinto	Vegetation cover change assessment on Yarraloola and Red Hill stations	$8,600	B Huntley, 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
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 *Stylidium* phylogeny and pollination project	Nil	J Wege
South Coast NRM	Conservation of the threatened Australasian bittern in south-western Australia	Nil	J Lane, 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
Terrestrial Ecosystem Research Network - AusPlots, Pilbara Corridors, Australian Transect Network, Bush Heritage Australia, The University of Western Australia	AusPlots Rangelands 2016 Western Australian Campaign	$120,000	S van Leeuwen, M Hislop
The University of Western Australia, Chevron, Roy Hill, Eubio Consulting	Defining biologically significant units in spinifex (*Triodia* spp.) for improved ecological restoration in arid Australia	$770,000	M Barrett

Partners	Project Title	External Funding	Departmental Involvement
The University of Western Australia, National Marine Fisheries Service (USA), Northern Territory Museum, Western Australian Museum, Queensland Department of Environment and Science, Pendoley Environmental, AUSTurtle	Skeletochronology and stable isotope analyses of flatback turtles	$400,000	S Whiting, T Tucker
The University of Western Australia, University of Tasmania, Australian National University, Australian Institute of Marine Science, CSIRO	Investigating the effect of recreational fishing using 30 years of data from Ningaloo Marine Park, a meta-analysis	Nil	T Holmes, S Wilson
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
University of Adelaide, Upsalla 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, M Pennifold
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
Western Australian Marine Science Institute, The University of Western Australia	Long-term monitoring of seagrass communities on behalf of the Cockburn Sound Management Council	$55,000	S Strydom, M Rule
Western Australian Marine Science Institute	Project 1.1.1 Distribution and predictors of benthic biodiversity	$31,000	J Huisman
Western Australian Marine Science Institute	Industry-Government Environmental Meta-database	Nil	A Kendrick, F Mayer
Western Australian Marine Science Institute	Project 1.2.3 Saltwater crocodiles (*Crocodylus porosus*) in the north-west Kimberley	$30,000	A Halford

Partners	Project Title	External Funding	Departmental Involvement
Western Australian Marine Science Institute	Project 1.2.2 Key biological indices required to understand and manage nesting sea turtles along the Kimberley coast	$1,200,000	T Tucker, S Whiting
Western Australian Museum	Woodside Collection Project (Kimberley)	Nil	J Huisman
Western Australian Museum	*NatureMap*: data sharing and joint custodianship	Nil	P Gioia
Yawuru Park Council, Nyamba Buru Yawuru Aboriginal Corporation	A biological survey of Nimalarragan Wetland, Broome	$20,000	A Pinder, M Lyons, M Cowan

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	157
R Bunn	H Clark (BSc Honours)	Professor RL Mancera (Curtin University), Dr B Funnekotter (Curtin University)	How does seed maturity affect cell membrane composition and cryotolerance / cryosensitivity? A biochemical and biophysical study	2017 – 2018	157
R Bunn	K Ang (BSc Honours)	Dr B Funnekotter (Curtin University)	Orthodox but nonconformist: the perplexing problem of cryopreserving short-lived native orchid seeds	2017 – 2018	158
R Bunn	R Streczynski (BSc Honours)	Professor RL Mancera (Curtin University), Dr B Funnekotter (Curtin University)	Oxidative damage to cell membranes during cryopreservation	2017 – 2018	158
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	159
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	159
M Byrne, R Binks	T Robbins (BSc Honours)	Prof S Hopper (The University of Western Australia)	Molecular and morphometric analysis of two disputed subspecies, *Banksia seminuda* subsp. *remanens* and *Banksia occidentalis* subsp. *formosa*	2018 – 2018	159

DBCA Officer	Student	Academic	Project Title	Duration	Page
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	160
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)	*Reedia spathacea* F. Muell.: a study of phylogeography, population structure and co-occurrence	2016 – 2020	160
M Byrne	N Delnevo (PhD)	Dr E van Etten (Edith Cowan University), Prof W Stock (Edith Cowan University)	*Conospermum undulatum*: insights into genetics and ecology of an endangered species	2017 – 2019	161
M Byrne	A Lullfitz (PhD)	Prof S Hopper (The University of Western Australia)	Vegetation responses to Noongar land management practices in old and young landscapes	2014 – 2018	161
D Coates	R Dillon (PhD)	Prof M Waycott (The University of Adelaide), Dr R Standish (The University of Western Australia)	Mating systems, reproductive output and progeny fitness of translocated plant populations compared to wild populations	2017 – 2019	162
D Coates	L Monks (PhD)	Dr R Standish (The University of Western Australia)	Factors affecting the success of threatened flora translocations	2016 – 2019	163
D Coates	K Lambert (BSc Honours)	Prof H Lambers (The University of Western Australia)	Evaluation of Gondwana link restoration projects with reference to mycorrhizal communities in remnant and revegetated land	2017 – 2017	163
A Cochrane	F Gray (PhD)	A/Prof P Poot (The University of Western Australia)	Effects of climate change on the Australian native grass *Neurachne alopecuroidea*: provenance response to drought from germination to early seedling vigour	2017 – 2018	164
J Cosgrove	B Owen (PhD)	Dr CS Hallett (Murdoch University), Dr F Valesini (Murdoch University), Dr NR Moheimani (Murdoch University)	Phytoplankton in a microtidal temperate estuary: drivers, historical trends and future predictions	2017 – 2020	164
R Davis	T Hammer (PhD)	Prof L Mucina (The University of Western Australia)	Phylogeny, systematics and evolution of the Australian arid-zone *Ptilotus*	2015 – 2018	164
J Dunlop	R Chan (BSc Honours)	Dr P Spencer (Murdoch University)	Mate choice, sexual selection and spatial ecology based on parentage testing in the northern quoll	2017 – 2017	165
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 – 2019	165

DBCA Officer	Student	Academic	Project Title	Duration	Page
R Evans	C Tuckett (PhD)	Dr T Wernberg (The University of Western Australia), Dr T de Bettignies (The University of Western Australia)	Improving our understanding of high latitude coral communities in temperate Western Australia: biogeography, latitudinal growth patterns, connectivity-fecundity-recruitment and competitive tolerance to seaweeds	2015 – 2017	166
S Fossette-Halot	J Stubbs (PhD)	Dr M Vanderklift (The University of Western Australia), Dr N Mitchell (The University of Western Australia)	Foraging ecology and energetics of green turtles in the Ningaloo coast world heritage area	2017 – 2019	166
N Gibson	C Slee (PhD)	Dr E van Etten (Edith Cowan University), Prof W Stock (Edith Cowan University)	The assessment of ecosystem risk in *Banksia* woodlands of the Swan Coastal Plain, Western Australia	2017 – 2019	167
T Holmes	J Haberstroh (MSc)	D McLean (The University of Western Australia), Dr T Langlois (The University of Western Australia)	Baited video, but not diver video, detects greater abundance of legal sized target species within sanctuary zones at Ningaloo Marine Park	2017 – 2019	167
T Holmes	I Lindgren (MSc)	D McLean (The University of Western Australia), Dr T Langlois (The University of Western Australia)	Distribution and behaviour of two morphologically distinct shark species in Ningaloo Marine Park	2017 – 2019	168
T Holmes	B Vaughan (MSc)	Dr T Langlois (The University of Western Australia), D McLean (The University of Western Australia)	Assessing the drivers of fish distribution patterns in Ningaloo Marine Park	2015 – 2017	168
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K Trayler	B Poh (PhD)	R Tweedley (Murdoch University), Dr J Chaplin (Murdoch University), Prof N Loneragan (Murdoch University)	Evaluating the population genetics, recruitment limitations and release strategies of western school prawns during a restocking program in the Swan-Canning Estuary	–	188
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A Wayne	A Seidlitz (PhD)	Dr K Bryant (Murdoch University), Dr N Armstrong (Murdoch University)	Survey methods and ecology of the numbat population at the Upper Warren region	2017 – 2019	189
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S Whiting	J Stuart (PhD)	Dr T Fleming (Murdoch University), B Bateman (Curtin University), Dr P Adams (Murdoch University)	Evidence based management of foxes adjacent to turtle beaches in Western Australia	2016 – 2019	190
S Whiting	P Wilson (PhD)	Dr M Thums (Australian Institute of Marine Science), Dr C Pattiaratchi (The University of Western Australia), Dr M Meekan (Australian Institute of Marine Science)	Understanding the early offshore movement of flatback turtle hatchlings and the effects of anthropogenic light	2015 – 2019	190
S Whiting	E Young (PhD)	Dr R Vaughan-Higgins (Murdoch University), Dr N Stephens, Dr K Warren (Murdoch University), Dr L Yeap (Murdoch University)	The health status of marine turtles in northern and western Australia	2016 – 2019	191
S Whiting	B Bentley (BSc Honours)	Dr N Mitchell (The University of Western Australia), Dr J Kennington (The University of Western Australia), Dr O Berry (CSIRO)	Predicting the effect of climate change on embryonic flatback and green sea turtles in the Kimberley region of Western Australia	2014 – 2017	191
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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 PhD 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 also being assessed, and builds on work completed through the South Coast Integrated Fauna Recovery Project (IFRP) in order to provide essential information for optimising the effectiveness of control programs for this introduced predator in south coast ecosystems.

In the past 12 months a further 50 feral cat stomach samples collected from nature reserves and national parks in the south coast region and Bush Heritage properties in the Fitzgerald-Stirling area have been analysed, and samples collected for stable isotope analysis. Funding, secured through Bush Heritage Australia, has enabled purchase of additional GPS radio-collars for deployment in the Gondwanalink Landscape in spring 2018. Data from 32 monitoring sessions have been cleaned for native prey availability modelling.

How does seed maturity affect cell membrane composition and cryotolerance / cryosensitivity? A biochemical and biophysical study

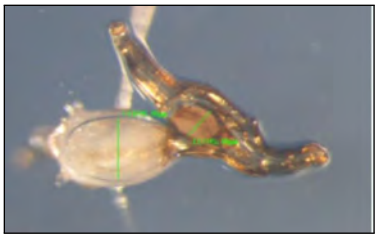
STP 2019-010

Scientist(s): R Bunn
Student: H Clark (BSc Honours)
Academic(s): Professor RL Mancera (Curtin University), Dr B Funnekotter (Curtin University)

Development of desiccation protocols is crucial for successful cryopreservation. Experimentation with seed axes of *Syzygium paniculatum* has indicated that optimal drying time and water content is very difficult with

these recalcitrant-seeded species.

S. paniculatum expresses much reduced survival as water content of the seed axes is reduced. Further development of this critical step will be needed to develop successful desiccation for recalcitrant-seeded species. Preliminary analysis of the lipid content of cell membranes shows significant differences between species and tissue type abundancy of sterol glucosides, sterol esters, phytosterols and glycerolipids. No large double-bond index differences between species or tissue types were observed. The preliminary data suggests that the best possibility of getting post-cryopreservation survival for embryonic axes of both species is with selection bases on maturity and the use of longer cryo-protective agents incubation time.



Orthodox but non-conformist: the perplexing problem of cryopreserving short-lived native orchid seeds

STP 2019-009

Scientist(s): R Bunn
Student: K Ang (BSc Honours)
Academic(s): Dr B Funnekotter (Curtin University)

Orchid seeds are usually desiccation tolerant but recent research has indicated that their storage life is compromised by premature loss of viability under standard storage conditions and even following cryostorage. This study investigated why orchid seeds behave in this manner.

Firstly, artificial seed aging experiments were carried out at high temperature and humidity to simulate natural aging albeit in much shorter time frames, to provide estimates of seed longevity between the species *Caladenia latifolia* and *Microtis media*. Results indicate a significant drop in seed viability and germinability at 40^{o}C compared to 35^{o}C (at the same relative humidity); however, this is more pronounced in *C.latifolia* seeds which suggests that *M. media* seeds possess the potential for greater intrinsic longevity in storage compared to *C. latifolia*. Further experimentation is needed to verify these preliminary results and to ascertain whether differences in storage longevity exist between other orchid species. Secondly, the storage compounds of orchid seeds were analysed to determine what types of compounds are present in orchid seeds. Storage compounds such as sugars help to stabilise seed tissues during drying and storage, hence understanding the types and relative amounts of storage compounds will enhance our knowledge of orchid seed chemistry and potentially provide the means for overcoming short lived storage behaviour in orchid seeds.

Oxidative damage to cell membranes during cryopreservation

STP 2019-007

Scientist(s): R Bunn
Student: R Streczynski (BSc Honours)
Academic(s): Professor RL Mancera (Curtin University), Dr B Funnekotter (Curtin University)

It is important to understand the significance of lipid peroxidation damage to cell membranes during cryopreservation, and how this affects post-cryogenic survival. This is especially important for recalcitrant-seeded species as they are desiccation and temperature sensitive hence developing successful cryostorage poses significant challenges. The first phase of the study investigates the effects of antioxidants on mitigating desiccation stress in excised seed embryos of *Syzygium australe*, an Australian recalcitrant-seeded species.

Experiments to date show beneficial effect of the antioxidant, glutathione, in terms of meristem survival following desiccation and verified by fluorescent staining. Further experiments will be needed to refine the type, concentration and duration of treatment with other antioxidants that may also confer beneficial effects on pre- and post-cryostored seed embryo and shoot material.

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 southern boobook (*Ninox boobook*) is a cryptic owl species that may be declining in south-west Western Australia as a consequence of anthropomorphic impacts. This project aims to investigate boobook decline and identifying possible causes, such as secondary poisoning from anticoagulant rodenticides ingestion, across a series of landscapes impacted differently by human activity.

A review of the use of anticoagulant rodenticides in Australia has been published. This review documents non-target impact processes influencing exposure that may be unique to Australia, and compares Australian legislation governing anticoagulant use to legislation in other developed nations. Rodenticide concentration analysis in boobooks has been conducted and one paper published. Genetic analysis at nine microsatellite markers has been completed for >100 individuals. All blood samples have been processed to derive serum for *Toxoplasma gondii s*eropositivity testing. All data collected from the nest box study and associated occupancy surveys has been completed. Other papers are in preparation.

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 is an enigmatic species of ground dwelling parrot that is believed to occur across northern 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.

In Western Australia, work this year has included survey by acoustic recorders, and the recordings from this field work are currently being analysed. Habitat assessments have been made at the only nest found in Western Australia, and at several recently discovered roost sites, as well as in presumed unoccupied habitat. An attempt to track a foraging bird was unsuccessful due to higher than expected mobility. An invited paper was given in a threatened species symposium at the Australasian Ornithological Conference held in Geelong in November 2017.

Molecular and morphometric analysis of two disputed subspecies, *Banksia seminuda* subsp. *remanens* and *Banksia occidentalis* subsp. *formosa*

STP 2018-111

Scientist(s): M Byrne, R Binks
Student: T Robbins (BSc Honours)
Academic(s): Prof S Hopper (The University of Western Australia)

Banksia seminuda subsp. *remanens* and *B. occidentalis* subsp. *formosa* from Western Australia's south coast were described as subspecies in the late 1980s based on differences in leaf morphology, canopy density and height between them and their common subspecies. However, this status has since been rejected and

has led to dispute over their current classification. Historically, taxonomic decisions such as these have been based primarily on morphological traits, an approach that has provided many correct classifications. However, morphology alone is not always the most appropriate basis for assessment as it is not always under genetic control and therefore heritable, and where morphological differences are minor or variable (such as between infraspecies) differentiating taxa may not be possible by simple visual examination. These issues are further compounded by a lack of consensus on infraspecific definitions, characters to delimit them, and the degree of differentiation that constitutes recognition as distinct taxa. Nonetheless, contemporary analysis techniques in morphometrics and genomics are providing insight into taxonomic inconsistencies that may assist in resolving taxonomic boundaries. This research seeks to obtain information to resolve the subspecific classifications given for *B. seminuda* subsp. *remanens* and *B. occidentalis* subsp. *formosa*, hypothesising that both do constitute distinct subspecies. This project aims to conduct morphometric analyses to determine statistically how respective subspecies differ in their morphology; perform genomic sequencing of nuclear DNA to determine the presence and level of genotypic variation within and between respective subspecies; and finally, use this information to determine subspecies delimitation in each species.

Samples of leaves were collected for morphometric and genomic analysis from populations of *B. seminuda* subsp. *remanens* and *B. occidentalis* subsp. *formosa* on coastal headlands, along with populations of their common subspecies. Samples were also collected from a location for each species where the two subspecies appeared to intergrade. Information on plant height and floral density of canopy was also collected at each location. Morphometric analysis is underway. DNA has been extracted from all samples and sent for genomic sequencing.

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 adaption 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.

Fieldwork was undertaken to collect range-wide samples of leaf material for the generalist parasite, *Nuytsia floribunda*, and sympatric non-parasitic species, *Banksia ilicifolia*. Nuclear DNA was sequenced for both species using next generation sequencing technologies and analysis of this data is now underway. Field sites were also identified for the limited host-specific parasitic species, *Amyema gibberula* subsp. *tatei*, and its main host, *Hakea recurva* subsp. *recurva*, and fieldwork for collection of leaf samples has commenced.

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 it's 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.

Extensive fieldwork to investigate morphology and collect genetic specimens has been completed. Genotyping with microsatellites has been completed and data analysis is almost complete. Significant departure from Hardy Weinberg Equiibrium was found across all populations indicating 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 high, suggesting populations have been isolated over long time frames. Samples for cpDNA sequencing will be selected in order to delve deeper into molecular investigation of the species history. The research to date has been presented in a conference poster.

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 on the Swan Coastal Plain has been increasing during the last 60 years, making land use change one of the most important drivers affecting biodiversity. *Conospermum undulatum* is an endemic plant species of the Swan Coastal Plain, and is now ranked as 'Vulnerable' under Western Australia legislation. The significant reduction in population size, connectivity and density of remnant patches are likely to constrain the sexual reproduction of this species by altered plant-pollinator interactions and expression of inbreeding depression because of reduced gene flow between unrelated individuals. Moreover, putative hybrids between *C. undulatum* and more common *Conospermum* species have been identified on a morphological basis.

During the 2017 flowering season, data was collected from 210 individuals in 12 populations looking for differences in fruit and seed production, and seedling germination and mortality, among different populations. Results indicate that plant reproductive effort is not affected by any of the population variables. However, the proportion of seeds produced per inflorescence is positively and significantly related to population size, connectivity and floral display, indicating that habitat fragmentation is posing a threat to this endemic species. Interestingly, fruit production per inflorescence appears to be affected only by the population floral display, that is, the potential of the population to attract pollinators. This result suggests that, besides pollen limitation, genetic factors that prevent the development of the embryo and result in empty fruits may be present in small and disconnected populations. More ecological surveys during the 2018 flowering season are planned and a microsatellite library has been developed to investigate the genetics of *C. undulatum.*

Vegetation responses to Noongar land management practices in old and young landscapes

STP 2016-001

Scientist(s): M Byrne
Student: A Lullfitz (PhD)
Academic(s): Prof S Hopper (The University of Western Australia)

This project aims to improve our understanding of the nexus between Noongar culture and contemporary floristic distributions, ultimately informing both biodiversity conservation in the South-West Australian Floristic Region (SWAFR) and connection of Noongar people with Country. Through collaborative research with southern coastal Noongar Elders and archaeologists, the project explores how specific cultural activities may have influenced biodiversity within the SWAFR through a series of investigations examining vegetation patterns and processes. Specific areas of focus include testing for evidence of Noongar plant resource concentration around cultural nodes and botanical differentiation between nodes of varying historic cultural use; phylogeographical investigation of culturally important taxa in the genus *Platysace*; investigations of resource concentration effects of edible*Platysace* tuber harvest; and an analysis of Noongar land use patterns in relation to landscape age and propensity to disturbance.

The phylogeographical work is testing the hypothesis that humans are a historical vector influencing the distribution of the staple Noongar food species, *P. deflexa* and *P. trachymeniodes*. Leaf samples were collected and analysed from 49 populations of *P. deflexa*, *P. trachymenioides*, *P. effusa*, *P. compressa* and *P. juncea* located in inland areas southwest of a line from Northampton to the Cape Arid National Park. Noncoding chloroplast DNA regions, trnS-trnG52S, trnV-ndhc and psbD-trnT were examined in a total of 239 individuals, using a range of analytical tools. Genetic patterns in the species were different, supporting expectations based on aboriginal use. The pattern in *P. effusa* (which has no known cultural significance) showed a general pattern of high population divergence, low gene flow and multiple refugia, consistent with a long evolutionary history and past climatic oscillations and persistence in a highly fragmented landscape. In contrast, patterns in *P. deflexa* and the southeastern part of the range of *P. trachymenioides* showed higher gene flow estimates, less divergence between populations, and ancestral common haplotypes that are consistent with anthropogenic influences. A manuscript outlining methods, results and findings is currently in late draft.

Mating systems, reproductive output and progeny fitness of translocated plant populations compared to wild populations

STP 2017-027

Scientist(s): D Coates
Student: R Dillon (PhD)
Academic(s): Prof M Waycott (The University of Adelaide), 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. The key aims of this project are to: (1) compare the mating systems of translocated populations with those of both large and small wild populations; (2) determine how the reproductive output and progeny performance of translocated populations compares to wild populations; and (3) assess the efficacy of using measures of mating system parameters and reproductive potential to provide an indication of translocation success or failure. The findings from this study have a number of potential implications for not only assessing long term translocation success, but for also improving translocation design and establishment technologies.

Genotyping has commenced on seed extracted from collections from 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. Pollination studies have commenced to assess pollination adequacy in the translocated population and suspected differences in pollinator type between montane and lowland populations. Fitness trait studies have commenced in a common garden experiment involving 1,100 seedlings of *B. brownii* from montane, lowland 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. Reproductive output measurements and seed were collected from two natural and two translocated populations of *Acacia rhetinocarpa.*

Factors affecting the success of threatened flora translocations

STP 2017-026

Scientist(s): D Coates
Student: L Monks (PhD)
Academic(s): Dr R Standish (The University of Western Australia)

Determining the factors influencing success of plant translocations is an important component of recovery programs. 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. Aspects of translocation success to be investigated include: (1) undertaking a meta-analysis of past plant translocations in Western Australia to provide an insight into factors that contributed to successful outcomes; (2) assessing genetic diversity and mating systems of translocated compared to the wild, source populations of *Lambertia orbifolia*; (3) development of a Population Viability Analysis (PVA) model for translocated and wild populations of *Acacia cochlocarpa* subsp. *cochlocarpa* to determine if translocated populations have similar population trajectories as wild populations; and (4) undertaking a cross pollination study of *Schoenia filifolia,* to evaluate whether the genetic composition of the founder populations contributes to translocation success.

Leaf material and seed was collected from *L. orbifolia* for the genetic diversity and mating system studies, detailed monitoring of *A. cochlocarpa* has been finalised for the PVA study, genetic material and seed was collected from *S. filifolia*and the initial cross pollinations undertaken in a glasshouse trial.

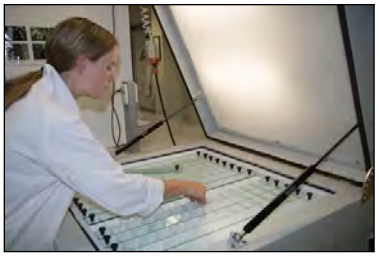
Evaluation of Gondwana link restoration projects with reference to mycorrhizal communities in remnant and revegetated land

STP 2017-018

Scientist(s): D Coates
Student: K Lambert (BSc Honours)
Academic(s): Prof H Lambers (The University of Western Australia)

This project will examine mycorrhizal community parameters (abundance, ratios of arbuscular (AM) and ectomycorrhizal (EM) associations and diversity) of selected host species in revegetation areas compared with nearby remnant bushland. The study is being undertaken within the Fitz-Stirling bioregion in the south of Western Australia, in sites that form part of the Gondwanalink restoration initiative. Additionally, a growth experiment will be undertaken using site-collected soils to help further decipher the underlying causes for observed responses. These findings may be used to guide revegetation practices in the future, and provide suggestions for the best chance of reinstating or maintaining natural mycorrhizal communities.

Mycorrhizal community parameters of selected host species were examined in revegetation areas compared with nearby remnant bushland with two types of mycorrhizal associations, arbuscular and ectomycorrhizal, investigated for abundance through root colonization counts. A growth experiment using site-collected soils and field studies were used to assess mycorrhizal presence and abundance. No clear differences were found in mycorrhizal root colonization levels between the revegetated sites and their associated remnant bushland. These findings suggest, that at least for the mycorrhizal associations investigated, mycorrhizal recovery in these revegetated sites has resulted in levels now comparable to adjacent remnant bushland.



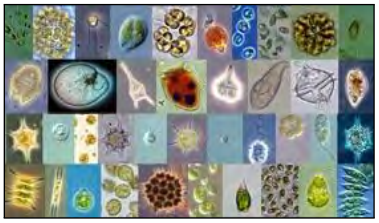
Effects of climate change on the Australian native grass *Neurachne alopecuroide*a: provenance response to drought from germination to early seedling vigour

STP 2017-039

Scientist(s): A Cochrane
Student: F Gray (PhD)
Academic(s): A/Prof P Poot (The University of Western Australia)

Neurachne alopecuroidea is a common perennial grass species occurring over a wide climatic range in the south-west of Western Australia. It is an ideal species for investigation of the impacts of a warming and drying climate on plant regeneration due to it's widespread occurrence. Variation in temperature and rainfall conditions experienced by populations across the species geographic range make it possible to detect differences in potential climate change responses and relate these to adaption to local climate. This project aims to address a knowledge gap in seed germination biology for this widespread but potentially ecologically important species.

This Honours project has been completed and a manuscript entitled 'Germination response to variation in temperature and moisture availability among populations of the Australian native grass *Neurachne alopecuroidea'* has been submitted to the journal *Folia Geobotanica.*



Phytoplankton in a microtidal temperate estuary: drivers, historical trends and future predictions

STP 2018-097

Scientist(s): J Cosgrove
Student: B Owen (PhD)
Academic(s): Dr CS Hallett (Murdoch University), Dr F Valesini (Murdoch University), Dr NR Moheimani (Murdoch University)

Understanding the historic conditions of the Swan-Canning Estuary is important to help predict future conditions and guide management activities. This project aims to identify spatial and temporal patterns in the phytoplankton community of the estuary and relate these to environmental drivers. Phytoplankton and a range of environmental variables have been monitored across the estuary since 1994; however, this long-term data set has not been extensively analysed. Multivariate analyses of the phytoplankton data and correlation with key hydrological and physico-chemical variables will facilitate the characterisation of current and past phytoplankton community patterns and their drivers across space and time.

Predictions for future phytoplankton dynamics will be made for the system, by applying historical relationships between phytoplankton and environmental drivers to modelled predicted hydrological and climatic trends. The data set for this project has been sourced and data analysis is in progress.

Phylogeny, systematics and evolution of the Australian arid-zone *Ptilotus*

STP 2015-012

Scientist(s): R Davis
Student: T Hammer (PhD)
Academic(s): Prof L Mucina (The University of Western Australia)

Ptilotus is a genus of annual and perennial herbs and shrubs, common in arid and semi-arid areas of Australia. This project is addressing three key questions on the evolution of *Ptilotus*: (1) what key phylogenetic patterns in the genus can help explain its evolutionary success in arid Australia; (2) how do biogeography patterns in the genus relate to its evolution; and (3) how have *Ptilotus* species adapted to low soil phosphorus in Australia over evolutionary time.

A substantially resolved phylogeny for *Ptilotus* including a well-supported backbone has been derived from genomic data, along with an improved understanding of the phylogenetic position of the unusual Australian genera *Kellita* and *Omegandra*.The new genus Wadithamnus,an anomalous and phylogenetically disjunct species from the Arabian Peninsula previously included in Aerva, has been described. Species boundaries in the widespread Australian *P. exaltatus-P. nobilis* and *P. gaudichaudii* groups have been resolved and papers published. An experiment investigating a novel phosphorus uptake mechanism and unusual root morphology in a range of *Ptilotus* species has been established.

Mate choice, sexual selection and spatial ecology based on parentage testing in the northern quoll

STP 2017-046

Scientist(s): J Dunlop
Student: R Chan (BSc Honours)
Academic(s): Dr P Spencer (Murdoch University)

Promiscuous mating appears to be a common strategy in marsupials, with possible benefits including genetic 'bet-hedging' and reducing the relatedness of individuals occupying an area. Female northern quolls (*Dasyurus hallucatus*) occupy small, exclusive territories, are highly promiscuous and produce a single litter of six to eight young per year, whereas males have large, overlapping home ranges. This honours study aimed to: (1) determine the paternity of pouch young of known mothers in two wild populations of northern quoll; (2) determine whether mating systems differ between a mainland and island site; (3) explore the relationship between paternity and physical characteristics of males and (4) use the information generated from this new knowledge to infer the system of mate choice, and if there is strong sexual selection by female northern quolls.

Tissue from northern quoll pouch young and mothers was collected from an island and mainland site where northern quolls are at high densities; Indee Station near Port Hedland, and Dolphin Island in the Dampier Archipelago. Paternity analysis of 16 litters comprising 100 pouch young was tested using microsatellite markers. All 16 litters were fathered by more than one male, with up to eight males fathering eight young in the one pouch. It has been hypothesised that females drive this fiercely competitive mating strategy to ensure fitness of offspring, resulting a nearly complete die-off of males following the mating season.

For the Dolphin Island population, male reproductive success (number of pouch young fathered) appeared to be linked to smaller body size. Identified fathers on Dolphin Island weighed significantly less than males that were not identified as fathers. Female northern quolls on Dolphin Island consistently have six nipples, whereas females on the mainland have eight. Both of these reproductive characteristics appear to favour conservative numbers of smaller offspring, rather than riskier investments in large offspring, in an unpredictable island environment. These selective pressures are lessened on the mainland, where animals have more capacity to disperse. This project was completed and a manuscript is in draft.

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 northern quoll is a threatened species occurring across northern Australia. This project seeks to enhance conservation of northern quolls in the Pilbara by providing managers with a better understanding of the threats most likely to impact population persistence. Specifically, this project aims to: (1) calculate monitoring effort required to effectively assess occupancy changes in northern quoll populations; (2) assess how factors, such as fire frequency, habitat structure and predator densities, influence quoll occupancy; and (3) examine fine scale

habitat use by northern quolls using GPS collars at various sites across the Pilbara.

Significant progress has been made across all three aims. Using pre-existing live trapping and camera trapping data we have modelled the comparative effectiveness of both methods in detecting changes in occupancy. This data will be implemented within continuing survey and monitoring efforts to ensure project resources are distributed in a cost efficient manner. Cameras traps spread over 120 sites in operation for a combined total of over 23,600 traps nights collected 1,501 northern quoll detections along with hundreds of feral cat and wild dog detections. By combining this data with detailed habitat assessments, we are in the process of constructive comprehensive occupancy models that will provide crucial insight into the way in which quolls interact with both predators and their environment. Finally, we have begun deploying GPS collars set to elucidate the fine-scale spatial and temporal movements of northern quolls beyond the scope of any previous research.

Improving our understanding of high latitude coral communities in temperate Western Australia: biogeography, latitudinal growth patterns, connectivity-fecundity-recruitment and competitive tolerance to seaweeds

STP 2015-005

Scientist(s): R Evans
Student: C Tuckett (PhD)
Academic(s): Dr T Wernberg (The University of Western Australia), Dr T de Bettignies (The University of Western Australia)

This project will establish baseline data for high latitude coral community dynamics across broad latitudinal and associated temperature gradients. A multidisciplinary approach will involve experimental studies, spatial and temporal analysis, molecular and histological techniques to determine variation in corals and their suitability to temperate systems. Study locations will be chosen to represent specific temperature gradients across tropical, warm temperate and cool temperate latitudes. Study species will represent more temperate or cosmopolitan species found in Western Australia, which will be determined from previous and current studies. The objectives of this project are to: (1) explore the biogeographical patterns of coral distribution from tropical into temperate areas; (2) to establish a point of reference for future change; (3) to determine phenotypic plasticity and population fitness across latitudinal and associated temperature gradients in important population parameters, including growth, fecundity, recruitment, connectivity and competitive tolerance to seaweeds; and (4) to examine the environmental suitability of temperate reefs as refugia for corals under elevated ocean temperatures on progress required.

All fieldwork and analyses have been completed. Results demonstrate that the distribution of coral assemblages at high latitudes is influenced by temperature, light availability and competition with seaweeds. These corals typically spawn in the warm summer months, although fecundity and recruitment are low compared with those at lower latitudes. Warming of sea water at high latitudes has facilitated expansion of corals to temperate reefs; however, these corals are still vulnerable to heat stress and further expansion may be moderated by light availability and population processes.

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), Dr N Mitchell (The University of Western Australia)

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) describe the movement of foraging and nesting

green turtles using satellite tags; and (3) use dynamic energy budget modelling to investigate allocation to growth and reproduction throughout the lifecycle.

Fieldwork was conducted in January 2018 to assist with satellite tagging and collection of stable isotope samples from nesting female green turtles. Laboratory work has commenced to prepare stable isotope samples for analysis. The results obtained from embryonic development and dynamic energy budget modelling studies were presented at the Ningaloo Outlook Symposium in March 2018. A manuscript on embryonic development has been submitted to *Physiological and Biochemical Zoology.* Revisions to a dynamic energy budget manuscript have been submitted to *Journal of Sea Research.*

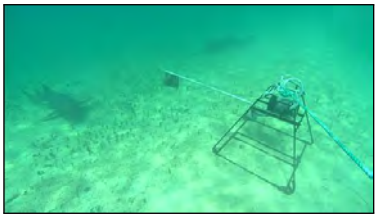
The assessment of ecosystem risk in *Banksia* woodlands of the Swan Coastal Plain, Western Australia

STP 2017-035

Scientist(s): N Gibson
Student: C Slee (PhD)
Academic(s): Dr E van Etten (Edith Cowan University), Prof W Stock (Edith Cowan University)

Banksia woodlands of the Swan Coastal Plain are part of the south-west Western Australian biodiversity hotspot and have been subjected to extensive clearing. These *Banksia* woodlands are now listed as a threatened ecological community (TEC) by the Commonwealth through the *EPBC Act.* There are numerous floristic community types (FCTs) within *Banksia* woodlands, of which several are threatened. An example is the Swan Coastal Plain floristic community type 20a (SCP20a) (*Banksia attenuata* woodlands with species rich dense shrublands). The threatening processes impacting on *Banksia* woodland include further land clearing, fragmentation, weed invasion, inappropriate fire regimes, altered hydrological processes, disease due to *Phytophthora cinnamomi* and a drying climate. This project aims to address knowledge gaps for improving the understanding of *Banksia* woodland floristic communities with a focus on SCP20a through a meta-analysis of Swan Coastal Plain data, combined with targeted assessment of new sites and re-assessment of existing sites with the aim of detecting change. The study also aims to integrate spatial analysis of environmental factors with biological data to identify predictive capability and assess risk to *Banksia* woodlands using the IUCN Red List of Ecosystems criteria, with reference to alternative risk assessment techniques.

Targeted field surveys were completed in the second half of 2017 for a selection of SCP20a sites. Acquisition of additional SCP floristic plot data has been made through collaboration with other researchers and data custodians. The development of a floristic meta-dataset for the SCP is in progress to review the position of *Banksia* woodlands within the context of improved availability of survey data acquired since the original FCTs were defined. This will be followed by a meta-analysis of the consolidated dataset.



Baited video, but not diver video, detects greater abundance of legal sized target species within sanctuary zones at Ningaloo Marine Park

STP 2017-049

Scientist(s): T Holmes
Student: J Haberstroh (MSc)
Academic(s): D McLean (The University of Western Australia), Dr T Langlois (The University of Western Australia)

Assessment of sanctuary zone effectiveness in marine reserves is an important component of management. This project compared data on fish size and abundance from remotely operated baited video (BRUV) to information collected using diver operated video (DOV). Both methods were deployed at the same Ningaloo Marine Park sites, inside and outside no-take sanctuary zones, focusing on spangled emperor (*Lethrinus nebulosus*) that are targeted by recreational fishers. Data from BRUV demonstrated that the abundance of fish that can be legally caught and retained by fishers (>41 cm TL) was statistically higher in sanctuary zones than in

recreational areas, where fishing is permitted. However, data from DOV failed to detect a statistical difference in the size of fish in sanctuary and recreational zones. These findings help determine which methods are most appropriate for monitoring fish, especially when assessing the impacts of recreational fishing. The thesis has been approved and a manuscript has been prepared and submitted to a journal for publication.

Distribution and behaviour of two morphologically distinct shark species in Ningaloo Marine Park

STP 2017-048

Scientist(s): T Holmes
Student: I Lindgren (MSc)
Academic(s): D McLean (The University of Western Australia), Dr T Langlois (The University of Western Australia)

Understanding abundance of species on reef systems and the factors that influence them is important for marine park management. This project used baited remotely operated underwater video to investigate factors that influence the distribution of grey reef sharks (*Carcharhinus amblyrhynchos*) and white tip reef sharks (*Triaenodon obesus*) at Ningaloo Marine Park. Both species were more abundant as the distance from boat ramps increased. In addition, white tip reef sharks were strongly influenced by the underlying structural complexity of the reef and were more abundant at places where the structural complexity of the reef was highly variable. These results indicate that proximity to boat ramps has a negative influence on shark abundance at Ningaloo, although the strength of this relationship varies among species, and for white tip sharks habitat is a better predictor of abundance. The thesis has been submitted and a manuscript is being prepared for publication.

Assessing the drivers of fish distribution patterns in Ningaloo Marine Park

STP 2016-014

Scientist(s): T Holmes
Student: B Vaughan (MSc)
Academic(s): Dr T Langlois (The University of Western Australia), D McLean (The University of Western Australia)

Fish are key components of marine ecological systems. This project examined the influence of fishing on fish assemblages across the reef slope and deeper water areas of Ningaloo Marine Park. The study compared fish communities in sanctuary zones and fished areas using stereo-baited remote underwater video methods. The findings indicated that the abundances of targeted fish populations inside and outside of sanctuary zones were variable, with limited evidence to suggest positive sanctuary zone effects at these depths. It is likely that habitat related characteristics are a greater driver of fish assemblages under current conditions. Fish communities were heavily stratified by depth, indicating that multiple depth gradients should be incorporated into marine park planning and monitoring processes. As such, this body of work represents a significant contribution to science-based management of Ningaloo Marine Park. This study has been completed and a manuscript is being prepared for publication.

The role of *Kyphosus* spp. in reef ecosystems

STP 2012-217

Scientist(s): A Kendrick
Student: A Turco (PhD)
Academic(s): A/Prof G Hyndes (Edith Cowan University)

Little is known about herbivory on temperate reefs and even less is known about the species that play an

important role in this key ecological process. Kyphosids are an abundant family of herbivorous fishes that are widely distributed in the southern hemisphere, and especially in temperate and tropical waters of Australia. However, the ecology of these fishes in temperate latitudes is poorly understood. The aim of this project is to determine the role of Kyphosids in algal herbivory in reef ecosystems, and the factors affecting their grazing activity.

The study found Kyphosids were more abundant in high-relief areas and juveniles mainly inhabited shallow inshore reefs, suggesting these are important nursery habitats. Dietary analyses demonstrated that sympatric and morphologically similar species can assume different functional roles (i.e. as browsers or grazers), inferring that species level identifications are required in monitoring and research programs to avoid erroneous estimates of herbivorous activity. This project has been completed and a manuscript is being prepared.

Conservation genetics of the critically endangered *Styphelia longissima*

STP 2019-005

Scientist(s): S Krauss
Student: W Thomas (BSc Honours)
Academic(s): (The University of Western Australia)

Styphelia longissima(Ericaceae) is a critically endangered shrub located north of Perth 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 in *S. longissima* were examined. A survey of the population was undertaken with 221 of 947 adults, and 106 seeds collected from 14 maternal plants, genotyped using 14 microsatellite markers. The resulting genetic data were used to obtain measures of genetic diversity, generate mating system parameters and assign paternity.

Allelic richness and levels of expected heterozygosity were higher than predicted and reflect high levels of genetic diversity in *S. longissima*. Outcrossing rate was moderate at 66% and was consistent with values reported for other insect pollinated Australian plants. Extensive inbreeding was found, in both selfing and bi-parental inbreeding. Restricted pollen dispersal was evident, with 95% of matings occurring over a distance of 7 m or less and a mean pollen dispersal distance of 3.65 m. Currently, the population appears genetically healthy, with higher than expected levels of diversity and no evidence for inbreeding depression. This study provides baseline data on genetic diversity, mating system and pollen dispersal, which will assist the future monitoring and assessment of *Styphelia longissima*.

Optimising seed sourcing for effective ecological restoration

STP 2019-004

Scientist(s): S Krauss, D Merritt
Student: S Adhikari (PhD)
Academic(s): Dr E Veneklaas (The University of Western Australia)

Successful ecological restoration hinges greatly on sourcing germplasm from appropriate provenances. Local seeds are conventionally used, but rapidly shifting selection pressures under climate change has prompted the demand to enhance climate resilience in seed sources – so called 'climate-adjusted provenancing'. To assess the merit of this strategy, the variation in climate responses of *Stylidium hispidum* sourced from climatic extremes at the north and south of its distribution was tested via germination and early growth experiments under varied temperature and moisture regimes.

Northern provenance displayed some traits that are potentially climate adaptive and suggest higher resilience to hotter and drier conditions, although not all measured traits exhibited a northern provenance advantage.

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.

Field trials have been established and initial monitoring conducted. Soil microbiome analyses have been conducted and data are being analysed. Glasshouse growth trials with seedlings sourced from six provenances showed overall decreased stomatal conductance and decreased leaf water potential under low treatment. However, there was no provenance effect in either of these measures. Of most significance was that all the seedlings of northern provenances, Kalbarri and Eneabba, survived under low water treatments. Mortality was significant for all other provenances, providing evidence that northern provenance seedlings are more resilient to drought stress.

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.

A combination of pollinator observations, exclusion experiments and molecular analysis for paternity assignment have been used to track pollinator behaviour and pollen dispersal within populations of *Anigozanthos manglesii*. Results indicate that nectar-feeding birds (honeyeaters) are critical for effective pollination of *A. manglesii*, inbreeding depression is associated with selfing and nearest neighbour mating, and there is a decline in reproductive success with increasing mate distance.

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. Ecological genetic studies are required to assess these consequences, and their implications for the evolution and conservation of these plants. A combination of genetic techniques and field experiments with *Eucalyptus caesia* will be 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 patterns of seedling recruitment and survival over time; and (3) the consequences of bird pollination in range-wide genetic diversity.

Results to date indicate low levels of genetic diversity, strong genetic differentiation among populations, and no evidence for inbreeding depression in a rare recruitment event, suggesting that purging of genetic load as well as individual longevity explains the persistence of woody perennial plants endemic to granite outcrops, despite historically small population sizes.

Evaluating the co-evolution of the Albany pitcher plant (*Cephalotus follicularis*) and its associated pitcher-inhabiting wingless fly (*Badisis ambulans*)

STP 2017-053

Scientist(s): T Macfarlane
Student: N Kalfas (PhD)
Academic(s): Prof M Waycott (The University of Adelaide), Dr J Conran (The University of Adelaide)

The Western Australian pitcher plant (*Cephalotus follicularis*) captures insect prey in its pitchers as part of its nutrition. A specialised insect, the fly (*Badisis ambulans*), has a relationship with *Cephalotus* involving the larval stage of the fly developing in the liquid within the pitchers. The aims of this project are to: (1) understand the nature of the relationship between the plant and the insect; (2) to improve knowledge of the poorly known life history of the insect; (3) study the genetic structure within and between populations of both species; and (4) investigate whether the two organisms have co-evolved.

Genetic analysis of populations of *Cephalotus* showed that overall the plant has relatively low genetic diversity between populations but four genetic groups were identified, which show a geographical pattern. Experiments investigating the postulated mutually beneficial relationship between the plant, the pitcher-inhabiting fly and the ant prey, showed that the plant does not require the flies but fly presence reduces putrefaction of prey. Putrefaction is considered to be damaging to the plant's pitchers, reducing their longevity, so less putrefaction is a benefit the plant receives from the fly. Field and experimental work has been completed. Data analysis and writing of papers is in progress.

Psittacine beak and feather disease, avian polyomavirus and raven attacks in forest red-tailed black cockatoos

STP 2018-130

Scientist(s): P Mawson
Student: A Wallace (PhD)
Academic(s): A/Prof K Warren (Murdoch University)

The forest red-tailed black-cockatoo (*Calyptorhynchus banksia naso*) is a threatened species that is listed as Vulnerable. Forest red-tailed black-cockatoos have been adversely impacted by large-scale habitat loss, and viruses and predation present additional stressors to the species. Understanding the broader range of threats that may affect the species will assist in improving management practices and conservation outcomes.

This project aims to: (1) determine the prevalence of beak and feather disease virus and clinical infection in forest red-tailed black cockatoos and correlate these results with age and sex data and; (2) compare the age and sex demographics, health status and rehabilitation success of forest red-tailed black cockatoos affected by raven attacks with non-attached birds and identify any significant differences between the two groups. All sample collection has been completed and analysis is underway.

Optimising collaboration between secondary schools and informal science advisers: a stakeholder alignment perspective.

STP 2018-126

Scientist(s): P Mawson
Student: S Bickford (PhD)
Academic(s): Prof N Longnecker (The University of Western Australia)

Perth Zoo provides educational experiences that link to the school curriculum and can facilitate a connection between students and nature. This project will compare the goals, expectations and practices of teachers, informal educators and students participating in excursions in order to identify common areas of alignment and areas for improvement. Case studies will include excursions to Perth Zoo and Perth Hills Discovery Centre. This knowledge will be used to strengthen collaboration for the benefit of informal science institutions, schools and students. Data collection is complete and analysis is in progress.

The role of anthropomorphised flagship species in motivating zoo visitor participation in Tiwest Nightstalk.

STP 2018-125

Scientist(s): P Mawson
Student: A Smith (PhD)
Academic(s): Dr L Smith (Monash University)

Raising public awareness of local wildlife and their habitats is an important role of zoos. The Tiwest Nightstalk is a community education program that includes nocturnal spotlight surveys to record observed animals. This project aims to empirically test the theory that exposure to an anthropomorphised flagship species heightens perceptions of similarity to self, which then increases concern for the species and ultimately leads to pro-wildlife behaviour. The Tiwest Nightstalk program has been used for this project as a case study in a zoo setting. The project will test: (1) the species choice (based on varying levels of degrees of similarity to self); and (2) the type of educational materials (anthropomorphic versus scientific). Data collection is complete and analysis is in

progress.

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). Data collation has been largely completed and data analysis is in progress.

Optimising energy provision at Perth Zoo via a renewable energy micro-grid.

STP 2018-123

Scientist(s): P Mawson
Student: D Catto (MSc)
Academic(s): Prof C Lund (Curtin University)

Understanding the energy requirements of a large complex like Perth Zoo is important to guide energy efficiency and foster sustainability principles. This project will determine the optimal renewable energy micro-grid required to meet Perth Zoo's current and future (1-15 years) electricity needs, with the reduced costs and carbon emissions that are associated with such systems.

The project has been completed, with the key finding that an optimal system with reduced costs and emissions will not be possible for at least another 5 years given the current costs of additional renewable systems that could feasibly be deployed on Perth Zoo site, and current and projected costs of electricity sourced from the energy grid.

Social dynamics in a tufted capuchin group following the introduction of a novel male

STP 2018-122

Scientist(s): P Mawson
Student: M Bourrouosman, S Jeffries (3rd year)
Academic(s): Dr G Newland (Curtin University)

Tufted capuchins (*Sapajus apellaare*) are primates that originate from the Amazon rainforest in South America. This project observed and recorded the responses of an established tufted capuchin family group to the

introduction of new breeding-age male. The addition of the new male in the presence of the existing dominant male (now contracepted) was necessary to achieve breeding and studbook outcomes for this species in the Australasian region. All of the observations and data collation have been completed and analyses are in progress.

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 wild populations.

This research is investigating group dynamics and the impact of alterations in group composition in Javan gibbons. The project is also studying the process of pair-bond formation and maintenance in Javan gibbons and comparing pair-bond interactions with targets proposed in the *Best Practice Guidelines for Gibbon Translocation and Rehabilitation*. Data collection is complete and data analyses is in progress.

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. Behavioural observations are underway and tiger faecal samples have been collected.

Monitoring the behaviour of ghost bats before, during and after the reproductive season

STP 2018-116

Scientist(s): P Mawson
Student: A Smith (MSc)
Academic(s): Dr B Jackson (Murdoch University)

Ghost bats (*Macroderma gigas*) are endemic to Australia and are listed as Vulnerable. They are currently found in genetically isolated populations throughout northern Australia. This project was designed to observe

and quantify the behavior, and in particular interactions, of both male and female bats over the reproductive period with the aim of identifying areas of current captive management practice that may be changed to improve animal welfare and breeding outcomes.

Social behavioural interactions were shown to be influenced by breeding status, enclosure size and the daily maximum temperature. While further research is needed to underpin successful captive breeding programs, the findings from this project assist in identifying areas for improvement in captive management practice, along with providing insight into the behaviours and interactions of ghost bats across the breeding and post-breeding seasons.

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)

This study aims to characterise and investigate the cause of Cockatoo Hindlimb Paralysis Syndrome (CHiPS) in Western Australian black cockatoos. To date, only Carnaby's cockatoos (*Calyptorhynchus latirostris*) have been consistently affected since 2012, with one possible case in a forest red-tailed black cockatoo (*Calyptorhynchus banksii naso*).

Necropsies have been performed on 30 Carnaby's cockatoos, a single red-tailed black cockatoo and a single Baudin's cockatoo (*Calyptorhynchus baudinii*). Gross necropsy identified moderate to severe adipose and skeletal muscle atrophy within the CHiPS group. Within the control group, a variety of traumatic injuries were present. Histopathology of the CHiPS group identified skeletal muscle atrophy and necrosis within hind limb and wing muscles. A variety of traumatic injuries and haemorrhage were present within the control group. An AChE assay has demonstrated no significant reduction of brain levels in the CHiPS affected birds compared to a reference interval. Statistical analysis comparing the CHiPS and control groups is pending. The Neuropathy Target Esterase assay has been completed and samples sent for toxicology analyses.

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 (The University of Western Australia)

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.

Surveys have shown that soil moisture and temperature can indicate whether a *G. alba* or *G. vitellina* population has been stable, or has declined. Sites where frogs are present have cool and stable temperatures and it is thought that warmer temperatures may be unsuitable for these species. The main aim of this research is to quantify the effect of temperature on development times of *Geocrinia* embryos, in order to estimate development rates across a range of realistic field temperatures. A development rate function fitted to this empirical data will allow estimation of the critical thermal maximum (CTmax) and will infer temperatures at which exposure would be lethal. An embryo collection trip and subsequent nest splitting was undertaken, with seven wild *G. vitellina* clutches being collected, containing 86 fresh embryos. Embryos were incubated at various temperatures and monitored. Warmer temperatures (25℃ and above) resulted in abnormalities and mortality. The temperatures

of the treatments were lowered and tadpoles developed normally. The tadpoles are being staged regularly to monitor their development rates and data analysis is in progress.

Epidemiology of the clinical syndrome 'lumpy jaw' in captive macropods: influence of housing and husbandry

STP 2018-107

Scientist(s): P Mawson
Student: J Rendle (PhD)
Academic(s): A/Prof K Warren (Murdoch University)

Lumpy jaw is a well-recognised cause of morbidity and mortality in captive macropods. The condition is complex, with a number of proposed causes. Treatments are often challenging, with low post-therapy survival rates. This study aims to: (1) determine the prevalence of lumpy jaw in captive and free-living populations of macropods; (2) identify housing and husbandry risk factors associated with the development of lumpy jaw; and (3) evaluate the efficacy of treatments for the disease.

Results indicate that the prevalence of lumpy jaw does not differ significantly between the Australian and European regions, yet regional differences in age, sex and study period were identified. Macropod genera most at risk were identified by comparing incidence rates and 95% confidence intervals. Institutional results showed that Perth Zoo had a significantly lower incidence rate compared to the other Australian institutions participating in the research.

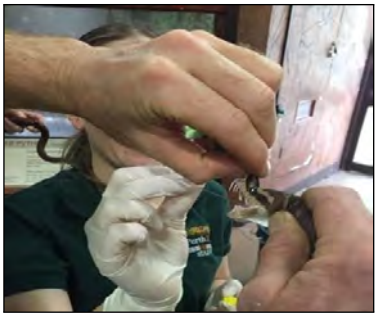
Disease risk analysis in support of the translocation of dibblers from the Jurien Bay Islands to Dirk Hartog Island National Park

STP 2018-106

Scientist(s): P Mawson
Student: P Moore (MSc)
Academic(s): Dr J McLelland (Murdoch University)

Dibblers (*Parantechinus apicalis*) are ranked as Endangered and 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. The aims of this project are: (1) produce a literature review of the Dasyuridae family with a specific focus on dibblers; (2) identify known hazards associated with the dibbler translocation and undertake a risk assessment; (3) investigate how commensal or potentially pathogenic parasites can be conserved through modification of therapeutic regimes to ensure native parasites are maintained in the reintroduced population; (4) consider disease risk management options and advise on future screening protocols for dibbler translocations; (5) supplement existing knowledge by collecting samples from wild caught animals for the captive breeding program for disease screening; and (6) present a summary of findings and the implications for managing future dibbler translocations.

Biological samples were collected from dibblers on the Jurien Bay Islands and from animals previously collected from the islands and transferred to Perth Zoo. Samples have been analysed and identified.



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)

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.

Laboratory work is underway and largely complete. Consideration is being given to the collection of further samples from wild pythons.

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 M Renton (The University of Western Australia), Dr E Veneklaas (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 such as timber production, tree health and mortality, and water yield need to be addressed. Individual-based modelling (IBM) is an ecological modelling approach that represents the 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.

A research proposal has been submitted and approved. Supplementary data for jarrah stand dynamics was recently collected. Supplementary data for karri stand dynamics will be collected in the coming summer months. A theoretical IBM is in the developmental phase. Field data analysis has recently commenced. After the theoretical IBM has been developed, the field data will be used to parametrize the tree growth model in a water limited environment. Effects of thinning on timber and water yield will then be simulated for the next 80 to 100 years using the model.

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 (University of Western Australia)

This project seeks to enhance understanding of the ecological response of karri forest to bushfire, focusing on the large O'Sullivan fire of February 2015. The study is examining the response of vegetation structure and composition to different levels of fire severity across four vegetation types (tall open eucalypt forest, open eucalypt forest, *Melaleuca*/*Allocasuarina* forest, *Banksia*/*Acacia* heathland). Fire severity is being determined from remotely sensed imagery. Field data are being collected at 48 sites and include details of overstorey composition and crown condition, understorey composition and cover, fungal community composition, soil nutrients and samples for analysis of fungal metagenomics. Seeds of dominant understorey species are also being tested to investigate temperature thresholds for survival during fire. To date, sites have been selected and initial site characterisations have been undertaken. Findings from an Honours study of initial post-fire vegetation recovery during the first year after fire are being prepared for publication.

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, low soil fertility in overburden substrates, exotic species invasion, and complex scheduling constraints on rehabilitation efforts. This project aims to address some of the problems faced in restoration in the Pilbara, focussing on: assessing the effectiveness of current practices of applying inorganic soil amendments in re-instating soil function, and improving seedling recruitment and survival; and exploring alternative amendments, including organic amendments, to improve plant establishment and long-term ecosystem sustainability.

Glasshouse experiments investigating the effects of the inorganic amendments urea and gypsum on seedling emergence have been completed. Results showed that soil amendments had limited influence on seed germination, and may be detrimental to seedling emergence and increase seedling mortality. However, plant growth was improved in alternative substrates when high doses of inorganic soil amendments were applied. The use of soil amendments in mine rehabilitation requires consideration of the trade-off between initial reductions in seed recruitment with later-stage seedling development. Field-based experiments in the Pilbara have been monitored at six-monthly intervals for soil respiration, plant photosynthesis, plant biomass and coverage, and soil nutrient and microbial analyses. Trials on a rock waste dump on a Pilbara minesite are monitored at quarterly intervals to determine the effects of inorganic (urea and gypsum) and organic (biochar, *Triodia* biomass) amendments on soil properties (microbial activity and diversity, soil nutrients) and seedling emergence and growth.

Improving the outcomes of seed-based restoration in cold and hot deserts: an investigation into seed dormancy, germination, and seed enhancement

STP 2019-022

Scientist(s): D Merritt, T Erickson
Student: O Kildisheva (PhD)
Academic(s): M Madsen (Brigham Young University)

Ecological restoration, largely using direct seeding, is commonly used in dryland systems that have been adversely impacted by intensive land management and industrial activities such as mining. However, direct seeding commonly results in less than 5% plant establishment. In drylands, plant recruitment is most constrained during germination and emergence, when plants are particularly sensitive to harsh environmental and edaphic conditions. Ensuring reliable and predictable plant establishment requires an understanding of species-specific germination traits and dormancy break requirements. Seed enhancements can further aid plant performance in the field. This project is addressing specific knowledge gaps in the use of seeds for restoration of drylands in two regions subject to large-scale degradation - a cold desert (Great Basin) in the western United States and a hot desert (Pilbara) in north-west Western Australia.

The project has produced first systematic investigation of seed dormancy and germination traits for 26 species of the Great Basin that are important for restoration in this region. A focus on dormancy-break of four herbaceous perennials demonstrated these species germinate in late winter or early spring, but that the thermal germination envelope is species-dependent, resulting in different germination niches. Cold stratification was most effective at promoting dormancy loss among all species. Chemical stimulants promoted germination in three species and may be a fast-acting alternative for seed pre-treatment. An examination of the effects of temperature- and abrasion-based on dormancy loss of seeds with physical dormancy found that abrasion-based techniques were most effective. Pneumatic scarification significantly enhanced germination and appears to be a fast, safe, and effective method with a potential to be scaled up for operational use. The development of seed enhancement technologies focused on *Triodia pungens* as a key grass species in the Pilbara, including the effects of seed priming and coating, and their combination, on seedling recruitment across differing levels of water availability. Priming promoted the highest germination, emergence, seedling size, and root development, and enabled establishment conditions. When not combined with priming, coating had a negative effect on seedling performance. Under non-limiting moisture, priming and coating resulted in the largest seedlings.

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 L Guzzomi (The University of Western Australia)

Irregular shapes and surface features on wild seeds hinder both the application of seed coatings and the flow of seeds through mechanical sowing equipment. The recent development of flash flaming technology effectively removes these surface features from seeds (florets) of *Triodia* spp., imparting a significant reduction in volume of the florets, and enhancing of their flowability, with little to no alteration on the viability of seeds. The initial success of flash flaming technology opens up more research opportunities to achieve seed-based restoration goals. This project will expand on the success of flash flaming demonstrated for *Triodia* species to other native species required for restoration through researching flash flaming procedures and settings for various native species, the development of a predictive model that describes the relations between the surface features of seeds and the optimal flash flaming procedures and settings, and the design and construction of new seed processing equipment including improved, large-scale flash flaming machinery.

Testing of flaming has been conducted on seeds of a number of new species, including those of *Austrodanthonia*, *Chloris*, *Cymbopogon*, *Eriachne*, *Gomphrena*, *Ptilotus* and *Stirlingia*. Results demonstrate that for all species, flaming can successfully improve seed geometry with little to no impact on seed germination. Design

of an improved seed flaming machine has been completed and the construction of a second and third flaming machine has commenced for future testing. Improvements to the original design include incorporation of a gear box into the motor to allow for continuous operation at low RPM over extended time periods, modifications to the inlet hopper, modification of stirring bars inside the drum, and automatic ignition of the burners.

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 L Guzzomi (The University of Western Australia)

Seed use in restoration is largely inefficient as a large number of native species are incompatible with direct seeding machinery due to complex morphological properties and attributes of seeds that cause blockages in conventional seeding machinery. Surface features of native seeds/fruits can comprise dense hairs, awns and lobes, causing them to block commercial drill seeders. This project aims to analyse current seed distribution methods and to design, construct, and test new multi-native species drill seeders compatible with seed of diverse native species for use in large scale restoration and rehabilitation. The primary objectives of such a drill seeder include the capability for controlling seed depth and spacing, sowing at rates applicable to large-scale restoration, and seeding over diverse landforms including rocky and sloping land.

An online survey was designed and circulated in 2018 to the international seed and restoration community to identify common limitations to direct seeding. There were 183 respondents to the survey, with the primary findings being that current direct seeding machinery lacks adequate controlling of seed sowing depth and spatial distribution, and that there is an inability to sow seeds of complex morphology over complex topographies. Experimental components of this project include field-trials in the Pilbara examining the optimal emergence depth of seeds of *Triodia pungens*. Results showed that broadcasting seed on the soil surface results in almost no germination, and that covering seeds to a depth of 5 mm yields optimal seedling emergence. Seedling emergence declines considerably at 10 mm depth, and almost no emergence occurs at 30 mm depth. Most mechanical seeders currently in operation are unable to control depth to this level of precision, particularly in the rocky and uneven terrain associated with mine waste dumps. Future designs of modifications to seeding machinery will focus on improving depth control in these conditions. Some initial modifications to current seeding techniques have been trialled through attaching an agricultural soil scarifier to the seeding unit, and testing of other purpose-designed and built prototype modifications aimed at precision incorporation of seeds into the soil.

Developing seed coating technologies for ecosystem restoration

STP 2018-148

Scientist(s): J Stevens, D Merritt
Student: S Pedrini (PhD)
Academic(s): Research Fellow A Cross (Curtin University), Prof K Dixon (Curtin University)

Seed coating is used to improve seed mechanical properties and deliver compounds that enhance performance in seeds and seedlings. Translating established seed coating technologies and practices from agricultural systems to Western Australian native species requires significant research with most knowledge confidentially retained by seed coating companies. This project aims to test seed coating technologies on native species to improve seed efficiency for Western Australian ecological restoration programs.

Specifically this project has: (1) undertaken a global synthesis of coating technologies and the drivers underpinning seed coating practices; (2) delivered a protocol development tool for seed encrusting and pelleting procedures for native species; (3) examined how seed pelleting may be a trade-off between native grass germination performance and mechanical integrity of the pellet; and (4) demonstrates how incorporation of signalling compounds into pellets may conform stress tolerance in native grass seedlings.

Population genomics of the burrowing bettong at Matuwa: a case study on the implications of genetic mixing

STP 2018-003

Scientist(s): K Ottewell, C Lohr, M Byrne
Student: K Rick (BSc Honours)
Academic(s): Dr J Kennington (The University of Western Australia)

The burrowing bettong (*Bettongia lesueur*) is a threatened macropod isolated to three offshore islands off the coast of Western Australia. As a result of geographical isolation, *B. lesueur* has been found to consist of two genetically distinct populations, which are currently listed as different subspecies. Multiple translocation attempts have been made to reintroduce *B. lesueur* back to mainland Australia, with Matuwa, located in the Goldfields region of Western Australia, being the first to establish a reintroduced population admixed from the two genetically distinct source locations. However, the genetic and demographic consequences of mixing genetically distinct populations is yet to be fully understood. Thus, through the use of next generation sequencing using reduced representation methods, this study aims to investigate the introgression between these two geographically isolated source populations and assess how this impacts genetic diversity and fitness across different generations.

To date, DNA extractions have been completed on 192 boodie samples from Matuwa encompassing samples from 2010-2017. These have been sent to the Australian Genome Research Facility for processing for ddRADseq analysis. Analysis of trapping data is underway to estimate survivorship and fecundity of the sampled individuals. A literature review and research proposal have been completed.

Genetic assessment and population viability analysis of translocations of black-flanked rock wallabies to Kalbarri National Park

STP 2017-025

Scientist(s): K Ottewell, M Byrne
Student: K Nilsson (BSc Honours)
Academic(s): Dr J Kennington (The University of Western Australia)

The black-flanked rock-wallaby (*Petrogale lateralis lateralis*) is nationally listed as Vulnerable (*EPBC Act*) and as Schedule 2 fauna in Western Australia (*Wildlife and Conservation Act*). Populations are restricted to suitable rocky habitat in a number of disjunct locations including the Great Sandy Desert, Little Sandy Desert, Cape Range, Wheatbelt and Barrow and Salisbury Islands. A small population (two animals) was recently re-discovered in Kalbarri National Park. This location is also part of a reintroduction program designed to provide an insurance population of *P. lateralis lateralis* in an area containing large areas of suitable habitat and with effective management of introduced predators (foxes, cats) and competitors (goats). In 2016, 23 rock-wallabies were translocated from the two largest wheatbelt populations and further translocations were undertaken in 2017 and 2018.

This project is evaluating the 2016 and 2017 rock-wallaby translocations from a genetic perspective and providing recommendations for future translocations. Using samples from the animals that were translocated to Kalbarri and samples from the 2015-2016 monitoring survey of Wheatbelt populations (including the two source populations, Mt Caroline and Nangeen Hill) the project is evaluating: (1) how genetically-representative the translocated animals were of the genetic diversity present in the source populations; (2) whether the sampling strategy of taking animals from different social groups was successful to minimise relatedness and maximise genetic diversity of the translocated animals; (3) how genetically-representative the source populations are of the genetic diversity present in the Wheatbelt; and (4) the use of scat DNA as a potential survey and monitoring tool. The project is also providing recommendations on the numbers of animals needed to be genetically-representative of the source populations and/or the Wheatbelt as a whole.

DNA extractions and microsatellite genotyping were completed on both the 2016 and 2017 translocated animals, as well as the male from the extant Kalbarri population and a single offspring from a translocated

wheatbelt female. Analyses on the genetic diversity and representativeness of the translocated populations have been completed and a population viability model developed. Rock wallaby scats were collected and analysed from the Mt Caroline wheatbelt population for a pilot study investigating the effectiveness of scat DNA analysis as a monitoring tool. The project has been completed and a manuscript is being prepared for publication.

Ecological responses of the northern quoll to a large-scale feral cat baiting program in the western Pilbara region, Western Australia

STP 2017-047

Scientist(s): R Palmer
Student: B Ross (PhD)
Academic(s): Dr B Murphy (Charles Darwin University), Prof J Woinarski (Charles Darwin University), Dr T Cremona (Charles Darwin University)

This project builds on an existing large-scale feral cat baiting and northern quoll (*Dasyurus hallucatus*) monitoring program in the Pilbara being undertaken by the department in partnership with Rio Tinto. The broader aims of the project are to: (1) investigate the nature of feral cat and northern quoll interactions at the landscape scale; (2) investigate how northern quolls may benefit from cat control; (3) assess the impact of the baiting program on the abundance of feral cats; and (4) explore means by which baiting protocols may be optimised.

Pre and post-baiting deployments of camera traps have been made across the baited and reference localities in 2017 and 2018 to calculate cat densities. Preliminary results indicate a reduction in cat numbers across the baited property, although high levels of reinvasion by cats was detected in early 2018. Demographic data has been obtained from four extended quoll trapping periods, hair and tissue samples have been collected for stress hormone analysis and genetic analysis, respectively. A further northern quoll foraging behaviour experiment was also completed in 2017. Data collected during this project to date was presented at the 2017 Australian Wildlife Management Society conference.

Aquatic invertebrate food resources in western swamp tortoise translocation sites

STP 2016-086

Scientist(s): A Pinder
Student: K Schmolz (MSc)
Academic(s): Adjunct Associate Professor G Gollmann (University of Vienna)

Seasonal claypans supporting the endangered western swamp tortoise (*Pseudemydura umbrina*) on the Swan Coastal Plain are predicted to become less suitable for this species in coming decades as rainfall declines further. One response to this threat is to seek alternative habitats in higher rainfall areas of the south-west of Western Australia. A trial translocation of western swamp tortoises into two wetlands along the south coast (near Northcliffe and east of Augusta) was undertaken in 2016. This project aimed to compare invertebrate food resources (biomass and composition in the wetland, plus gut contents) between these translocation sites and wetlands on the Swan Coastal Plain that currently support natural or translocated populations.

Aquatic invertebrate diversity and biomass were sampled at three western swamp tortoise translocation sites on two occasions in spring 2016, one at a translocation site in Moore River National Park and at the two trial translocation sites along the south coast. Western swamp tortoise gut contents were also obtained and biomass of food items calculated. The project has been completed and a presentation was delivered at the 19th European Congress of Herpetology, in Austria.

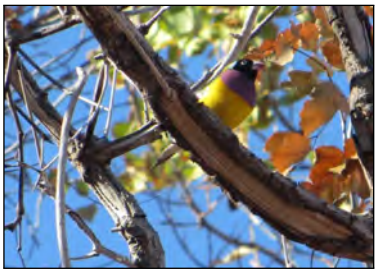
Is there a housing crisis in tropical savannas? Changing fire regimes, hollows and declining arboreal mammals

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% 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.

Current research activities in this second year of the study include calibrated ground-based observations of vegetation structure and tree hollow abundance and radio tracking arboreal mammals to document hollow usage on the Tiwi Islands. Research has also focused on analysing tree hollow distribution data from the Northern Territory. This work has revealed that aside from rainfall, soil depth and tree size, tree hollow abundance is driven by disturbance including fire regime, cyclones and termites. High frequency late dry season fires can result in reduced hollow abundance



Fine grained mosaic burning for enhancing Gouldian finch food resources and carbon storage

STP 2016-028

Scientist(s): I Radford
Student: A Weier (PhD)
Academic(s): Prof M Lawes (Charles Darwin University)

Gouldian finches benefitted from recent fire but are disadvantaged in their breeding by frequent fire. Nutritional benefits are derived from recent fire and low frequency fires, in terms of sorghum seed nutrient concentrations, which forms the dominant food source for the finch during the breeding season. The most successful breeding years are those after seasons with multiple small fires rather than seasons with a few large fires. This suggest that complex, fine grained fire mosaics are most beneficial to the Gouldian finch providing the greatest benefits in terms of breeding and feeding ecology.

Research in this project has highlighted the preference of Gouldian finches for burnt habitats in choice of breeding location. Finches preferred sites that were burnt infrequently (<once in three years). There was a nutritional benefit to finches at infrequently burnt sites with sorghum seeds produced at such having a greater nutritional value. Finches also had greater breeding success at the regional level after years with many small patchy fires, rather than after years with few but large and intense fires. This could be related to less frequent fires being experienced at the patch scale leading to better nutrition for breeding finches. It could also reflect greater abundance of perennial grass seeds in the wet season in patches in between multiple small fires. Sites burnt in early fires had higher sorghum seed density the following year which could also benefit Gouldian finches. This study has been completed and papers are being prepared for publication.

Mammal declines in northern Australia: science for conservation and recovery

STP 2016-027

Scientist(s): I Radford
Student: R Hohnen (PhD)
Academic(s): Dr S Legge (Australian National University), Dr C Burridge (University of Tasmania), Dr C Johnson (University of Tasmania)

This study was designed to investigate aspects of mammal decline in northern Australia using northern quoll, scaly tailed possums and golden backed tree rats as exemplar species under threat across the landscape from altered ecosystem processes such as changed fire regimes and predation by introduced predators.

The study has demonstrated that terrain ruggedness increased connectedness among northern quoll populations, while open habitats acted as an ecological barrier to gene flow. Golden backed tree rats and scaly tailed possums were found to benefit from the presence of unburnt habitats including rainforests and hollow bearing trees. However, both species also used burnt landscape elements for foraging, while avoiding some long unburnt habitats such as Triodia grasslands. These results emphasise the need for fine-grained fire mosaics, with a mix of burnt and unburnt habitat. Feral cats were found to have much lower occupancy rates in rugged sandstone habitats, even in the presence of increased mammal prey, than in open, structurally simple savanna habitats. This explains some of the reason small mammals may be scarce in open savanna vegetation, particularly after fire. This project is now completed.

Evolution of C_4 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 project aims to study the evolution of C_4 phototsynthesis in the genus *Tecticornia* (Chenopodiaceae) at the cell, protein and transcript levels. The genus includes two species identified as using the C_4 photosynthetic pathway and 39 species currently categorised as C_3 plants. Phylogenetic analyses of molecular sequence data will clarify relationships between species and identify any potential C_3-C_4 intermediate species in the genus, thus highlighting target species for detailed study.

The project has five objectives and the first three are complete. The first and second objectives were to measure anatomical features in appropriate C_4 and closely related C_3 species that were identified following the phylogenetic analyses of nrDNA internal and external transcribed spacer (ITS and ETS) sequences of species of *Tecticornia* and the closely allied *Salicornia*. The third objective was to measure protein abundance of photosynthetic proteins using immunoblotting techniques, including glycine decarboxylase P-subunit (GDC-P).

Work is currently being undertaken on the fourth objective, which examines location of GDC-P and ultrastructural characteristics at the electron microscope level. The research has optimised immunolabelling of tissue sections using the GDC-P antibody, and is quantifying labelling in different organelles and cell types. Work is also being undertaken to quantify ultrastructural characteristics in selected species. Preliminary work has also been completed on the fifth objective, which aims to measure transcript abundance of GDC-P.

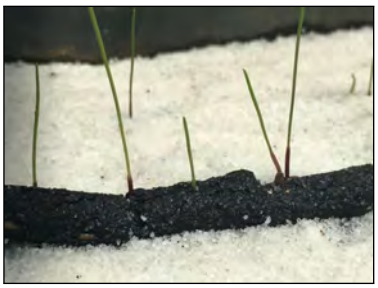
Movement and demographics of the reintroduced boodie (burrowing bettong) within a feral proof enclosure at Matuwa (Lorna Glen)

STP 2017-003

Scientist(s): C Sims
Student: T Moyle (BSc Honours)
Academic(s): Dr T Fleming (Murdoch University)

The Rangelands Restoration project at Matuwa (Lorna Glen) in the northern Goldfields aims to reintroduce several of the threatened mammals species that once occurred in the rangelands. This Honours project will determine habitat use, home range size and movement patterns of resident boodies (*Bettongia lesueur*) within the Matuwa enclosure. The information from this project will improve understanding of boodie ecology in this environment and inform selection of release site, release strategies and predator management for any future wild translocations of boodies outside the fence.

Field work for this project which involved, collaring and monitoring boodies from several warrens over several seasons, has been completed. Habitat mapping, home range and movement patterns are being analysed.



Restoring highly degraded *Banksia* woodlands through innovative seed enhancement technology

STP 2018-150

Scientist(s): J Stevens, A Ritchie, T Erickson
Student: V Brown (PhD)
Academic(s): Prof R Hobbs (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.

The project research proposal and literature review are in development. Seed pelleting formulations are being refined for *Banksia* woodland species and suitable field sites on the Swan Coastal Plain are being identified.

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.

Trials have been established to: (1) examine the role of waste rock materials in influencing seedling emergence; (2) identify soil water and temperature thresholds for seedling establishment; (3) examine the effect of rainfall

amounts on seedling performance and survival on waste rock dump environments and; (4) understand how seedling preconditioning to water stress may influence drought tolerance and survival in restoration programs.

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.

Several methods are currently being trialled to link plant stress responses with leaf spectral signatures including: (1) undertaking controlled drought experiments to determine optimal measurement methods for the two technologies; (2) initiating a multi-year monitoring experiment within restored systems and; (3) installing field irrigation experiments to assess the drought responses of plant species.

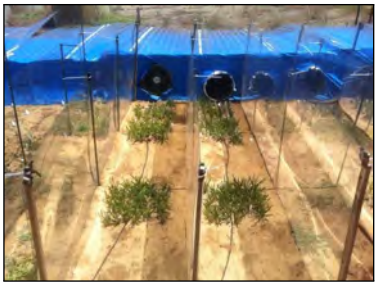
Soil-microbial-plant signals and effects on plant eco-physiological performance for mine site restoration

STP 2018-145

Scientist(s): J Stevens
Student: W Wong (PhD)
Academic(s): Dr J Yong (The University of Western Australia), A/Prof R Trengove (Murdoch University), 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 identified and isolated from the Western Australian natural systems. The project will also 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, including topsoil handling techniques.

Methodological advances in phytohormone detection and analysis have recently commenced for crop species and xylem sap has been collected from a range of Western Australian native species. Mine waste treatment with commercial microbial solutions is demonstrating benefits to plant growth, and linking plant physiological performance with tissue phytohormones is currently being assessed.



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 S Tomlinson (Curtin University), Dr A Guzzomi (The University of Western Australia), 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 particularly 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.

Data on wind dynamics has been collected from six key reference communities across Western Australia. To compare wind dynamics in reference sites to restoration environments, data has been collected from the reference *Banksia* woodland system and compared to sites that are 0, 2 , 6, 10 and 20 years post restoration. Data analysis is now underway.

How do species interactions drive community assembly of *Banksia* woodlands?

STP 2018-142

Scientist(s): B Miller, J Stevens
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. The exact cause of this mortality is unknown, though numerous factors may contribute to seedling death including herbivory, pathogen attack, and competition for limited resources, such as water and nutrients. 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) how do pairwise interactions between nitrogen fixing and non-nitrogen fixing seedlings affect their persistence or establishment (assuming 'establishment' is a seedling that survives past its second summer)?; and (3) does using varying densities of an annual grass (*Austrostipacompressa*) facilitate growth of seedlings from topsoil transfer?

Spatial mapping of individual perennial plants has been conducted in four restoration areas: 1, 3, 7 and 11 years old. Two additional field trials have been established including: (1) a two year trial to determine whether the spatial interactions of seedlings differs based on their ability to fix nitrogen; and (2) a trial understanding how six densities of *A. compressa* (0, 20, 165, 310, 455 and 600 *A. compressa* m^{-2}, representing natural densities) impact perennial seedling emergence and survival.

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)

Management decision making in relation to the water quality of the Swan-Canning Estuary is dependent on many factors, including an understanding of the estuarine metabolism of the system. The Swan Canning Estuarine Response Model (SCERM) is an important modelling tool and has been shown to capture seasonal and spatial variability in some physico-chemical parameters, and could be improved through targetted research. This project has focussed on refining research questions and on the detailed design and specification of mooring locations and scoping of logging / telemetry system arrangements.

Preliminary and short-term investigations involving dissolved oxygen sensor deployment at pilot sites suggests significant diel variation in dissolved oxygen concentration at nearshore locations, that are not currently captured in SCERM.

Evaluating the population genetics, recruitment limitations and release strategies of western school prawns during a restocking program in the Swan-Canning Estuary

STP 2018-091

Scientist(s): K Trayler
Student: B Poh (PhD)
Academic(s): R Tweedley (Murdoch University), Dr J Chaplin (Murdoch University), Prof N Loneragan (Murdoch University)

This project is linked to the restocking of western school prawns (*Metapenaeus dalli*) into the Swan-Canning Estuary and aims to improve an understanding of the species to guide the restocking program. The project will investigate the ecological factors and genetic diversity of the *M. dalli* population in the estuary, and whether the restocking program will have any adverse effects on the ecology and genetic diversity of the wild population of *M. dalli*.

Sampling in the estuary has been undertaken, encompassing twenty shallow water sites and 16 sites in deep waters over five years (2013-2018). The distribution, abundance and size structure of *M. dalli* has been investigated and results identified a positive relationship between *M. dalli* density in nearshore waters and surface water temperature. The spatial and temporal distribution of *M. dalli* differed significantly from the western king prawn (*Penaeus latisulcatus*) but was indistinct from the apogonid *Ostorhinchus rueppellii*, and two scyphozoans *Aurelia aurita* and *Phyllorhiza punctata*. Predation investigations determined that *O. rueppellii* is a major predator of juvenile prawns with implications for restocking strategies. Current focus of effort is on the evaluation of genetic diversity of the *M. dalli* population and potential for genetic markers of wildstock versus hatchery reared prawns.

Investigating habitat values of seagrass, macroalgae and wrack in the Swan Canning Riverpark

STP 2018-090

Scientist(s): K Trayler
Student: S Fulwood (PhD)
Academic(s): A/Prof G Hyndes (Edith Cowan University)

Seagrass plays an important role in the Swan Canning Riverpark by stabilising sediment and maintaining oxygen levels at the sediment/water interface. It is also an important food source for the black swan and is thought to support diverse and productive faunal assemblages. However, much of the information about the value of this habitat is gleaned from *Zostera* species in estuaries elsewhere. Relatively little is known of the biodiversity and ecological value of *Halophila ovalis*, the dominant species in the Riverpark. Macroalgae are commonly found in the lower reaches of the Riverpark in late spring and summer, and in recent years, large amounts of the macroalga *Chaetomorpha linum* have accumulated in response to favourable growth conditions. The macroalgae is fast-growing and is often considered a nuisance because it reduces light conditions to *Halophila* beds and can affect reproduction. This project is investigating the biodiversity and ecological values of *Halophila* meadows and *Chaetomorpha* accumulations. It will also determine the ecological value of accumulated wrack.

Two seasons of sampling invertebrates and fish communities have been completed. A major flood event in February 2017 impacted a third sampling event by causing major seagrass die-off. Stable isotope was delayed due to laboratory availability.

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 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 (UWR), 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.

To establish methods suitable for numbat monitoring in the UWR, fieldwork was conducted over two seasons (spring and autumn) to test driven transects, searches for numbat signs (diggings and scats), and camera-trap techniques (stationary and roving Reconyx and Swift-wide-angle camera models). Numbat detections from driven transects and camera-traps were too low to provide meaningful population measures. Searches for numbat signs returned promising results deemed suitable for occupancy modelling that incorporates detection probabilities. For upcoming fieldwork seasons, numbat sign searches will be designed to apply occupancy modelling approaches. Relationships between environmental variables including fire, timber harvesting and feral predator control and the UWR numbat population will be explored.

Investigating the impact of polyparasitism in translocated woylies and the effect of anti-parasite treatment on host fitness and survivability

STP 2014-008

Scientist(s): A Wayne
Student: A Northover (PhD)
Academic(s): Prof A Thompson (Murdoch University)

This project evaluates how fauna translocation and ivermectin treatment influence the parasite community, and host health in woylies (*Bettongia penicillata*). In particular, it is investigating how fauna translocations influence host-parasite dynamics and thus polyparasitism within a host and whether anti-parasite treatment has any benefit to host health and translocation success.

Following translocation, the parasite communities of translocated and resident woylies became more similar over time, with failure of some parasite taxa to persist and new host-parasite associations emerging. Ivermectin treatment did not significantly reduce the prevalence or abundance of any parasite taxa, or improve body condition in woylies. In translocated woylies, the presence of coccidia during the first three months following translocation, and increasing *Strongyloides*-like egg counts were associated with lower body condition. Results

from this project have contributed to five publications in peer-reviewed journals including: *EcoHealth, Biological Conservation, Parasites and Vectors*, and *Parasites and Wildlife*. Another five manuscripts are in preparation.

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), B Bateman (Curtin University), Dr P Adams (Murdoch University)

This project is investigating fox biology, distribution and 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.

Satellite transmitters have enabled the tracking of 14 foxes at a major flatback rookery in the Pilbara to understand their movements and home ranges. Results show limited seasonal variation with foxes maintaining distinct territories and patrolling these regularly. Foxes appear highly dependent on freshwater with artificial pastural watering points providing focal points. This study has provided information to assist in designing fox control measures which have now been implemented. Other parts of the study include diet analysis and trialling trap cameras to investigate fox detection and identification. The results from this study are being used to help the department and the pastoral leaseholder implement appropriate fox mitigation strategies at a local scale. This project has been communicated via various presentations including at several national conferences.

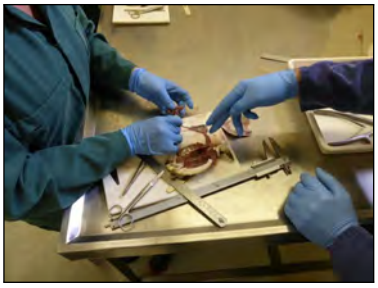
Understanding the early offshore movement of flatback turtle hatchlings and the effects of anthropogenic light

STP 2016-024

Scientist(s): S Whiting
Student: P Wilson (PhD)
Academic(s): Dr M Thums (Australian Institute of Marine Science), Dr C Pattiaratchi (The University of Western Australia), Dr M Meekan (Australian Institute of Marine Science)

Artificial light influences the orientation of hatchling flatback turtles and is a major pressure affecting this species in Western Australia. This project will investigate the extent of this influence under different light regimes and environmental cues and will quantify the impacts of light on hatchling turtles in nearshore waters. The aims of this PhD project are to: (1) determine if flatback turtle hatchlings are attracted to different types of light when in the water and for how long using acoustic telemetry, whilst concurrently looking at what natural cues (e.g. currents and waves) they may be using to initially move offshore; (2) determine if flatback turtle hatchlings use wave cues to move offshore, and explore the relationship between light cues and wave cues in a wave tank for both flatback and green turtle hatchlings; and (3) examine the relationship between distance from light source and hatchling attraction, as well as what effect lingering around light sources on permanent light-emitting structures has on the predation rates of flatback hatchlings.

All laboratory and field experiments have been completed. The field experiments used acoustic tracking to follow hatchlings through the nearshore zone at Thevenard Island with and without the influence of artificial light and with and without the influence of a jetty structure. The field experiments revealed high predation rates on hatchlings by fish using the jetty as a refuge. This project has initiated major discussions nationally in relation to coastal development infrastructure. The results of this project have been disseminated to a wide range of stakeholders including industry, government and academics through informal and formal presentations, including two international conferences.



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), Dr N Stephens, Dr K Warren (Murdoch University), Dr L Yeap (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 in the study as opportunities arise.

Blood samples from nesting and foraging flatback turtles have been collected. The foraging samples represent the first taken from the species globally. Necropsies are continuing on stranded turtles to help understand the causes of mortality. A new emerging disease *Streptococcus iniae* was found to be the cause of death for some neonate flatback turtles near Broome. This project has produced the basis for understanding the range of diseases impacting turtles in Western Australia. The results of this project have been disseminated through multiple presentations including one international symposium.

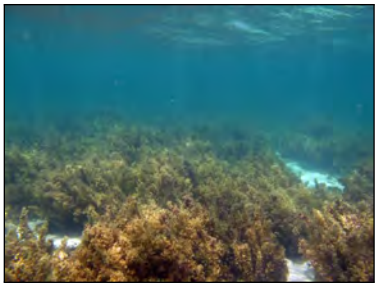
Predicting the effect of climate change on embryonic flatback and green sea turtles in the Kimberley region of Western Australia

STP 2014-014

Scientist(s): S Whiting
Student: B Bentley (BSc Honours)
Academic(s): Dr N Mitchell (The University of Western Australia), Dr J Kennington (The University of Western Australia), Dr O Berry (CSIRO)

Climate change has the potential to seriously impact sea turtle populations either through increasing temperatures, rising sea levels or increased storm events. Increasing temperature may have major implications for turtle embryo development by causing skewed sex ratios or increased mortality at the higher thresholds. This project is part of the WAMSI Kimberley node turtle project and is investigating climate change temperature impacts on turtle nesting using field and laboratory experiments and hind-casting models.

Eggs were collected from the Kimberley and Pilbara for incubation studies to determine pivotal temperatures and understand mortality from climate change. Environmental data was collected to model beach temperatures including predictive and hindcast models. Results determined the pivotal temperatures (i.e. the temperature at which 50% male and 50% female hatchlings are produced) for green (*Chelonia mydas*) and flatback (*Natator depressus*) populations. The impacts to turtle populations across the Kimberley were determined through predictive modelling, with the winter nesting flatback turtle population being the most vulnerable. This project, together with a previous study, will assist management by improving vulnerability and risk assessment across Western Australia. Results were delivered to stakeholders in more than 12 presentations, including an international symposium. The project is in the final stages of completion and several papers are being prepared for publication.



The effect of patch habitat networks in shaping the distribution, abundance and diversity of coastal fishes

STP 2015-006

Scientist(s): S Wilson
Student: J Van Lier (PhD)
Academic(s): Dr M Depczynski (Australian Institute of Marine Science), Dr C Fulton (Australian National University)

Seaweed-dominated habitats occur in tropical reef systems, where they play vital roles in supporting key species and processes. Habitat quality in seaweed patches, measured as canopy height, holdfast density or percentage cover, varies seasonally and can be a major driver of the presence and abundance of key functional and taxonomic fish groups. However, the relative influence of other seascape variables, such as patch shape, size and proximity, remains poorly understood. This project will study seaweed habitats at Ningaloo Marine Park, building on research in the region that has highlighted the importance of seaweed micro-habitat and intra-patch structure by including patch and inter-patch measures. The study will focus on fishes of the family Labridae (wrasses and parrotfishes), which are a diverse group of conspicuous reef fishes that span a wide range of trophic groups, body sizes, social structures, movement patterns and diel ranges. Specifically the project will: (1) establish how within and between patch habitat structure influences reef fish diversity within the Ningaloo lagoon; (2) explore how patch habitat configuration influences fish predator-prey dynamics; and (3) quantify how seaweed-associated fish assemblages respond to acute and unseasonal disturbances in patch-habitat condition.

All field data for this project has been collected and writing has commenced. A paper from this work has been accepted for publication in *Landscape Ecology*. The paper demonstrates that both seascape measures of connectivity among habitats and within patch measures of canopy structure are important predictors of fish diversity and should be considered in conservation planning.

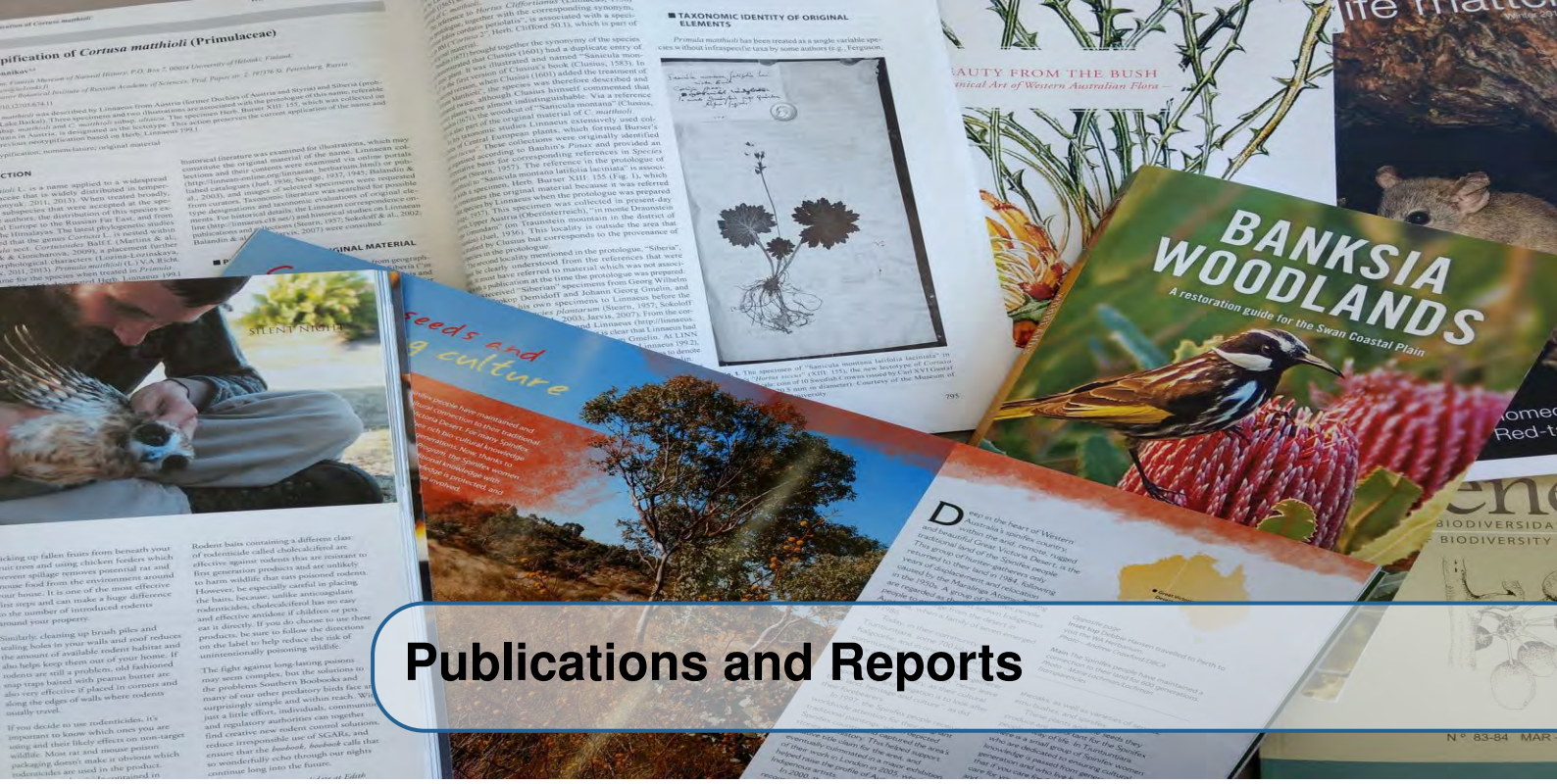
Variation in the intensity of periodic harvests in Fijian tabu areas and the effect on reef fish assemblages

STP 2012-235

Scientist(s): S Wilson
Student: J Goetze (PhD)
Academic(s): Dr T Langlois (The University of Western Australia)

Periodically harvested closures (PHCs) are a common form of fisheries management in Melanesia. However, it is unclear how effective PHCs are in maintaining the abundance of target species. This project initially identified suitable methods (diver operated video) and indicators (fish behaviour and biomass) for detecting changes in fish assemblages. Data from field studies in Fiji were then combined with information from the literature and meta-analyses used to demonstrate biomass of fish in PHCs is greater than in surrounding areas open to fishing. Analyses also found that to be successful, PHCs need to be closed to fishing for a considerable period of time, must be large, old and have high levels of fisher compliance.

The project has been completed and papers published. A meta-analysis published in the *Journal of Applied Ecology* found fish abundance often increases in tabu areas making harvest easier for fishers; however, the long-term benefits of this management practice to conservation are equivocal. An assessment of fish assemblages indicators of fishing, published in *Ecological Applications*, found fish behaviour is more sensitive to changes in fishing intensity than measures of biomass and abundance.



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Summary of Research Projects

Animal Science

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
Midwest	Carnarvon, Yalgoo	Rangelands	Cat eradication on Dirk Hartog Island	7
Pilbara	Pilbara	Rangelands	Conservation and management of the bilby in the Pilbara	10
South Coast, Warren	Jarrah Forest, Esperance Plains, Warren	South West, South Coast	Conservation of south coast threatened birds	17
Goldfields, Swan	Coolgardie, Swan Coastal Plain	Rangelands, Swan	Conservation of the graceful sun-moth	19
Pilbara	Pilbara	Rangelands	Decision support system for prioritising and implementing biosecurity on Western Australia's islands	9
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	21
Midwest	Yalgoo, Shark Bay	Rangelands	Dirk Hartog Island National Park Ecological Restoration Project – fauna reconstruction	4
Pilbara	Pilbara	Rangelands	Ecology and management of the northern quoll in the Pilbara	18
Wheatbelt	Avon Wheatbelt	Avon	Feral cat control and numbat recovery in Dryandra woodland and other sites	16
Pilbara, Swan	Pilbara, Swan Coastal Plain, Jarrah Forest	Rangelands, Swan	Genetic approaches for evaluating the contribution of the reserve system to fauna conservation	14
Kimberley, Pilbara	Northern Kimberley, Central Kimberley, Dampierland, Pilbara	Rangelands	Genetic assessment for conservation of rare and threatened fauna	12
South Coast	Jarrah Forest	South Coast	Gilbert's potoroo recovery plan	23
Kimberley	Victoria Bonaparte, Northern Kimberley, Ord Victoria Plain, Central Kimberley	Rangelands	Impact of cane toads on biodiversity in the Kimberley	20

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
Pilbara	Pilbara	Rangelands	Improved fauna recovery in the Pilbara – benefitting the endangered northern quoll through broad-scale feral cat baiting.	6
All Regions	Gascoyne	All Regions	Improving the use of remote cameras as a survey and monitoring tool	8
Goldfields	Gascoyne	Rangelands	Rangelands restoration: reintroduction of native mammals to Matuwa (Lorna Glen)	15
South Coast	Warren	South Coast	Understanding and reducing python predation of the endangered Gilbert's potoroo	3

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	32
Midwest	Geraldton Sandplains	Northern Agricultural	Climate change risks for biodiversity and ecosystem function in species-rich shrublands	27
Wheatbelt	Avon Wheatbelt, Swan Coastal Plain	Northern Agricultural, Avon, Swan, South Coast	Genetic and ecological viability of plant populations in remnant vegetation	41
Midwest, Goldfields, Wheatbelt, Swan, South Coast	Yalgoo, 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	47
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Herbarium collections management	31
All Regions	All IBRA Regions	All Regions	Interactive key and taxonomic studies of Myrtaceae tribe Chamelaucieae	26
South Coast	Esperance Plains	South Coast	Is restoration working? An ecological genetic assessment	25
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	44
Pilbara	Pilbara	Rangelands	Molecular characterisation of stinking passionflower (*Passiflora foetida*)	24
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 *Tephrosia* in Western Australia	34
All Regions	All IBRA Regions	All Regions	Seed biology, seedbank dynamics and collection and storage of seed of rare and threatened Western Australian taxa	46
All Regions	All IBRA Regions	All Regions	Strategic taxonomic studies in families including Amaranthaceae and Fabaceae (*Ptilotus, Gomphrena, Swainsona*) and other plant groups	28

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
All Regions	All IBRA Regions	All Regions	Systematics of the triggerplant genus *Stylidium*	38
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	40
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	39
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Taxonomy of selected families including legumes, grasses and lilies	36
All Regions	All IBRA Regions	All Regions	Taxonomy of undescribed taxa in the Ericaceae subfamily Styphelioideae, with an emphasis on those of conservation concern	33
Midwest, Wheatbelt, Swan, South Coast, Warren	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren	Northern Agricultural, Swan, South West, South Coast	Temperature thresholds for recruitment in south-west Western Australian flora	37
All Regions	All IBRA Regions	All Regions	The Western Australian Herbarium's specimen database	30
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	The Western Australian Plant Census and Australian Plant Census	29
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	40
Midwest, Goldfields, Wheatbelt, Swan, South Coast, South West	Avon Wheatbelt, Jarrah Forest, Esperance Plains	Rangelands, Northern Agricultural, Avon, Swan, South West, South Coast	The population ecology of critically endangered flora	45
Midwest, Wheatbelt, South Coast, South West	Geraldton Sandplains, 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	43

Ecosystem Science

DBCA 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	55
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?	49

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
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	67
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	69
South West	Swan Coastal Plain, Jarrah Forest	South West	Hydrological function of critical ecosystems	51
Swan	Jarrah Forest	Swan, South West	Hydrological response to timber harvesting and associated silviculture in the intermediate rainfall zone of the northern jarrah forest	68
South West, Warren	Jarrah Forest	Swan, South West	Identification of seed collection zones for rehabilitation	66
Swan, Warren	Jarrah Forest, Warren	Swan, South West	Long-term stand dynamics of regrowth forest in relation to site productivity and climate	61
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	62
Wheatbelt, South Coast, Warren	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren	Wheatbelt, Northern Agricultural, Swan, South West, South Coast	Protecting the safe havens: will granite outcrop environments serve as refuges for flora threatened by climate change?	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	52
Warren	Jarrah Forest, Warren	South West	Responses of terrestrial vertebrates to timber harvesting in the jarrah forest	59
Warren	Warren	South West	Restoring natural riparian vegetation systems along the Warren and Donnelly Rivers	58
Midwest, Wheatbelt, Swan, South Coast, South West, Warren	Murchison, Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren, Leeuwin-Naturaliste	Wheatbelt, Northern Agricultural, Avon, Swan, South West, South Coast	South West Wetlands Monitoring Program (SWWMP)	53
All Regions	All IBRA Regions	All Regions	Taxonomy, zoogeography and conservation status of aquatic invertebrates	56
Warren	Warren	South West	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	57
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Western Australian flora surveys	59
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Western Australian terrestrial fauna surveys	61
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Western Australian wetland fauna surveys	64

Marine Science

DBCA 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	72
Pilbara	Pilbara, Ningaloo	Rangelands	Effects of Gorgon project dredging on the marine biodiversity of the Montebello/Barrow Islands marine reserves	82
Pilbara	Pilbara, Pilbara (Offshore)	Rangelands	Habitat use, distribution and abundance of coastal dolphin species in the Pilbara	71
Pilbara	Pilbara, Pilbara (Nearshore)	Rangelands	Improving the understanding of West Pilbara marine habitats and associated taxa: their connectivity and recovery potential following natural and human induced disturbance	74
Pilbara	Ningaloo	Rangelands	Interactive effects of fishing and climate change on coral reef fish populations	84
Pilbara	Pilbara, Pilbara (Nearshore)	Rangelands	Long-term monitoring in the area of the proposed Dampier Archipelago marine reserves	70
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Marine Monitoring Program	77
Kimberley, Pilbara	Northwest Shelf	Rangelands	North West Shelf Flatback Turtle Conservation Program	79
Warren	WA South Coast	South Coast	Spatial and temporal patterns in benthic invertebrate communities of the Walpole and Nornalup Inlets Marine Park	83
Swan	Central West Coast	Swan	Spatial and temporal patterns in the structure of intertidal reef communities in the marine parks of south-western Australia	85
Pilbara	Carnarvon, Pilbara (Nearshore)	Rangelands	The influence of macroalgal fields on coral reef fish	75
Kimberley	Northern Kimberley, Oceanic Shoals	Rangelands	Understanding movements and identifying important habitats of sea turtles in Western Australia	76
Pilbara	Pilbara, Ningaloo	Rangelands	WAMSI 1 Node 3: science administration, coordination and integration	81
Kimberley	Oceanic Shoals, Bonaparte Gulf, Kimberley, Northwest Shelf, Cambridge-Bonaparte, Canning, King Sound, Eighty Mile Beach	Rangelands	WAMSI 2: Kimberley Marine Research Program	79

Fire Science

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
Warren	Jarrah Forest	South West	Burning for biodiversity: Walpole fine-grain mosaic burning trial	94
Swan	Geraldton Sandplains, Swan Coastal Plain	Northern Agricultural, Swan	Evaluation of synergies among fire and weed management in urban biodiversity and fire management	87

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
Warren	Warren	South West	Fire behavior and fuel dynamics in coastal shrublands	90
Goldfields, Wheatbelt, South Coast	Yalgoo, Avon Wheatbelt, Coolgardie, Mallee	Wheatbelt, Rangelands	Fire regimes and impacts in transitional woodlands and shrublands	93
South West	Warren	South West	Long term response of jarrah forest understorey and tree health to fire regimes	91
Kimberley	Northern Kimberley	Rangelands	North Kimberley Landscape Conservation Initiative: monitoring and evaluation	91
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	88

Kings Park Science

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Conservation biotechnology	101
All Regions	All IBRA Regions	All Regions	Conservation genetics	98
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	100
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Restoration science	97
All Regions	All IBRA Regions	All Regions	Seed science	96

Perth Zoo Science

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
Swan, South West	Swan Coastal Plain, Jarrah Forest	Swan, South West	*Geocrinia* frog breed and rear for release program	106
Swan	Swan Coastal Plain	Swan	Behavioural observations of Perth Zoo collection animals for animal welfare purposes and establishment of baseline data	105
Swan	Swan Coastal Plain	Swan	Dibbler breed for release program	107
Swan	Swan Coastal Plain	Swan	Numbat breed for release program	108
Midwest, Swan, South Coast	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	109
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	104
Swan, South Coast	Swan Coastal Plain, Mallee, Esperance Plains	Swan, South Coast	Western ground parrot captive breeding program	103

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
Swan, Warren	Swan Coastal Plain, Warren	Swan, South West	Western swamp tortoise breed for release program	107

Rivers and Estuaries Science

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
Swan	Swan Coastal Plain	Swan	Application of FlowCAM® to biological monitoring in the Swan Canning Riverpark	115
Swan	Swan Coastal Plain	Swan	Assessment of multi-wavelength fluorometer technology for chlorophyll *a* and gross phytoplankton composition estimation	114
Swan	Swan Coastal Plain	Swan	Dolphin health - toxicogenomics and pathology investigations	118
Swan	Swan Coastal Plain	Swan	Explaining foreshore vegetation die-off	114
Swan	Swan Coastal Plain	Swan	Investigating fish communities as an indicator of estuarine condition	113
Swan	Swan Coastal Plain	Swan	Model frameworks for estuarine reporting	117
Swan	Swan Coastal Plain	Swan	Seagrass monitoring and evaluation	111
Swan	Swan Coastal Plain	Swan	Stock enhancement of western school prawn: evaluation recruitment limitation, environment and release strategies	116
Swan	Swan Coastal Plain	Swan	Water Cleanser investigation	112

Remote Sensing and Spatial Analysis

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
All Regions	All IBRA Regions	Rangelands, Northern Agricultural, Avon, Swan, South West, South Coast	Remote sensing and spatial analysis for fire management	122
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Remote sensing monitoring	124
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Spatial analysis and modelling	123
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Spatial data management	120

Species and Communities

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Ecological communities conservation and recovery	127
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Fauna conservation and recovery	132
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Flora conservation and recovery	130

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
All Regions	All IBRA Regions	All Regions	Off-reserve conservation	129
All Regions	All IBRA Regions	All Regions	Wetland conservation	126

Ecoinformatics

DBCA Region	IBRA/IMCRA	NRM Region	Project Title	Page
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	BioSys – the Western Australian Biological Survey Database	135
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Online GIS biodiversity mapping (*NatureMap*)	137
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Provision of authoritative names of Western Australian taxa	136

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