Department of Parks and Wildlife

Science and Conservation Division
annual research report
2016–17

Department of
Parks and Wildlife

Acknowledgements

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Department of Biodiversity, Conservation and Attractions
(formerly the Department of Parks and Wildlife).

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Images
Front cover: Pilbara landscape. *Photo – Steven Dillon/DBCA*
Inset: Burning tree. *Photo - Stefan Doerr/Swansea University*;
Plant collecting. *Photo – Juliet Wege/DBCA*; Dibbler *Photo – Mark Cowan/DBCA*
Back cover: Flatback turtle *Photo – Liz Grant/DBCA*

Department of Parks and Wildlife

Science and Conservation Division

Annual Research Report

2016–2017

Department of
Parks and Wildlife

Director's Message

Through 2016-17 we continued to provide an effective science service to support the Department of Parks and Wildlife's corporate goals of wildlife management, parks management, forest management and managed use of natural assets. In supporting these core functions, we delivered best practice science to inform conservation and management of our plants, animals and ecosystems, and to support effective management of our parks and reserves, delivery of our fire program and managed use of our natural resources, as well as generating science stories that inspire and engage people with our natural heritage.

Our activities are aligned with management priorities and we deliver science expertise in our core areas of conserving threatened plants, animals and communities, landscape scale conservation, wildlife assets and inventory, WA Herbarium, bushfire research, marine monitoring and research, forest monitoring and research, wetland monitoring, hydrological monitoring, and biodiversity data management and distribution.Some highlights of activities this year have been lack of detection of cats on Dirk Hartog Island, translocation of rock wallabies to Kalbarri National Park and dibblers to Gunton Island, establishment of a flatback turtle monitoring program on Thevenard Island and aerial surveys of turtle nesting on beaches in the Pilbara, surveys for bilbies and rare plants in the La Grange development area of the Kimberley, vertebrate survey in the northern part of the Matuwa Kurrara Kurrara Indigenous Protected Area with traditional owners, determining meteorological drivers of extreme fire behaviour during the Waroona bushfire, and monitoring on FORESTCHECK sites burnt in the Lower Hotham bushfire. In addition, the excellence of our science and its application in management was recognised by *Western Shield* winning the Premier's Award for Excellence in Public Sector Management in the managing the environment category.

I am very pleased that we continue to be key partners in the Western Australian Marine Science Institution and the Western Australian Biodiversity Science Institute. Although these joint ventures are at different stages in their funding cycles, we continue to make significant contributions to their programs, and gain substantial benefit from our engagement in these initiatives.

I am also very pleased to have continued engagement with the National Environmental Science Program (NESP) hubs, as our staff provide a key perspective on the application of excellent science to address conservation and management needs. In particular, programs of the Threatened Species Recovery hub and the Northern Australia Environmental Resources hub are strongly aligned with those of our department in delivering applied science and research outcomes to support on-ground management.

Engagement with all our partners, both within the Department and externally, is an important component of how we deliver best practice science, and we continue to maintain excellent partnerships with universities, CSIRO, industry, not-for-profit organisations and other government agencies with many new projects and a large number of students that we co-supervise. We continue to build our relationship and engagement with traditional owners through research activities in the Pilbara, Western Desert and Kimberley

This report will be our last report as the Department of Parks and Wildlife. From 1 July 2017 Parks and Wildlife was amalgamated with Botanic Gardens and Parks Authority, Zoological Parks Authority and Rottnest Island Authority to become the Department of Biodiversity, Conservation and Attractions. A key function of the new department is to consolidate conservation science into one department to build and share knowledge of WA's biodiversity. I am confident we will continue to deliver excellence in applied science to support the core functions of the new department as we embrace the challenges and take advantage of the new opportunities provided by the amalgamation of these agencies.

Dr Margaret Byrne
Director Science and Conservation
July 2017

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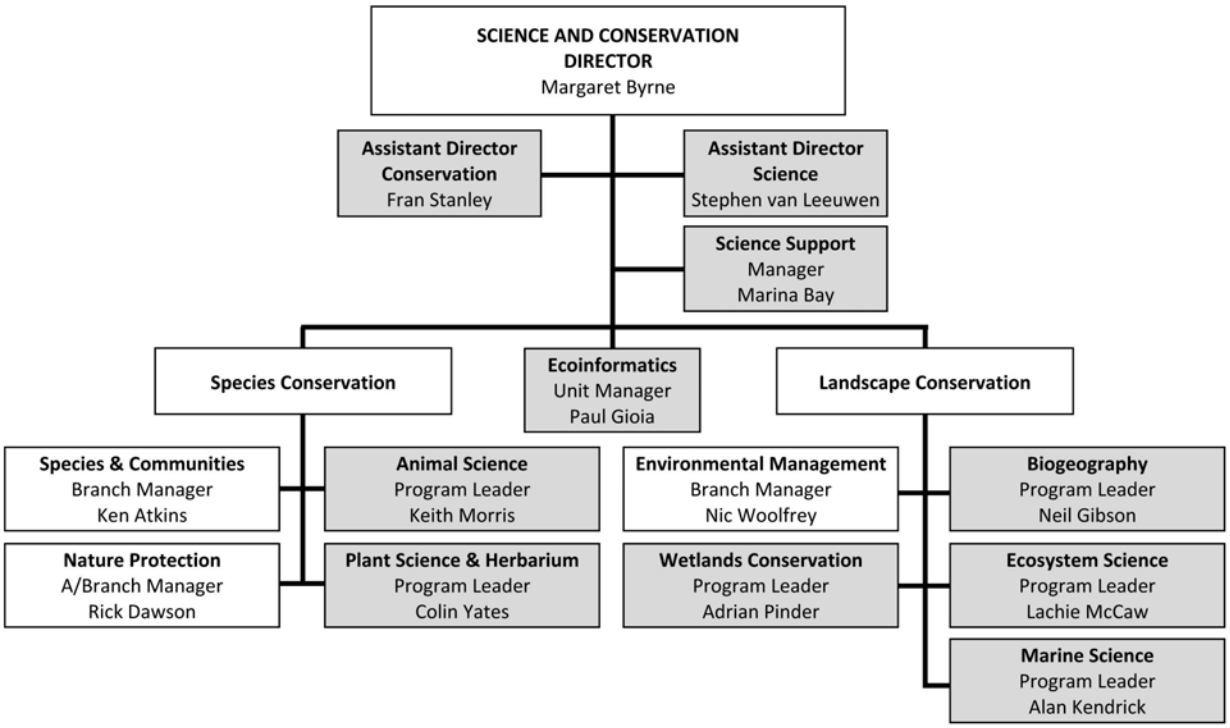
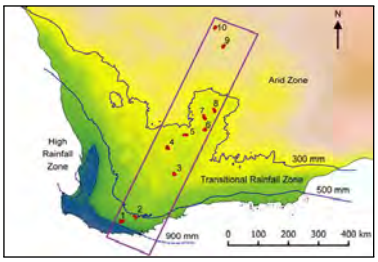
Service Delivery Structure



The Department of Parks and Wildlife is a science-based organisation where science provides the knowledge and information to support the Department's corporate objectives and priorities for wildlife management, parks management, fire management and managed use. The science function (shaded in structure diagram) of the Science and Conservation Division is integrated with policy and management functions reflecting the vital role of science and information in effectively managing Western Australia's plants, animals and ecosystems, and in the sustainable development of the State. Scientific knowledge forms a framework for engagement with the community in appreciating our natural places and with Aboriginal people on Country. Western Australia is a large state with unique biological diversity and the explicit knowledge required to manage Western Australia's unique environments requires local expertise. Parks and Wildlife's internal research capacity is extended and leveraged through attracting external investment to address Departmental priorities, and through strategic collaborations and partnerships.

Biogeography

Program Leader: Neil Gibson The Biogeography Program undertakes biological surveys to provide information on the biodiversity and nature conservation priorities within Western Australia. Surveys provide data on the distribution of plants and animals, and enable an understanding of regional patterns in their composition and distribution. Targeted surveys of specific regions, broad habitat types or selected plant and animal groups are also undertaken. Knowledge obtained from surveys complements the site-specific studies commissioned by other land managers, such as resource companies, and is used to provide the foundation for biodiversity planning and natural resource management across Western Australia. Collaborative associations are strong with the Western Australian Museum, Australian Museum, and other herbaria and museums throughout Australia, and with universities, cooperative research centres, CSIRO and other research institutions. Partnerships also exist with traditional owners, resource companies and the environmental consulting industry.



South-Western Australia Transitional Transect (SWATT)

SP 2013-003

S van Leeuwen, N Gibson, M Byrne, M Langley

Context

The South-Western Australian Transitional Transect (SWATT) is one of four national ecological transects or plot networks that traverse key Australian terrestrial ecosystems. The principal purpose of the transects is to measure selected biodiversity attributes along with biophysical processes, which will inform key ecosystem science questions and assist with the development and validation of ecosystem models. Transects will enable benchmarking and subsequent monitoring of trends in ecological condition in response to continental-scale biophysical processes such as climate change.

Aims

- Define, describe and understand the floristics and vegetation communities on deep sand plains across the transect to provide a baseline for monitoring change and impacts of disturbance, e.g. fire.
- Identify sensitive, important or significant species and communities in the sand plain vegetation community and provide management recommendations.
- Determine whether soil community turnover reflects plant community turnover.
- Determine whether isotope analysis indicated species sensitivity to climate gradients.

Progress

- Data on the floristics and vegetation communities of sand plains has been analysed and a paper describing turnover published in *PLoS ONE*.
- Plant specimens have been lodged in the Western Australian Herbarium.
- Metagenomic DNA sequencing has been undertaken from soil samples from plots.
- Laboratory analysis of 43 species occurring in six or more plots along the transect has been undertaken to determine community isotope signature. Isotope analysis for 50 sample of *Eucalyptus salmonophloia* and *E. salubris* has been undertaken to determine signatures for widespread species.

Management implications

A more detailed understanding of the beta-diversity patterns and vegetation structural attributes of the sand plains will enable improved assessment of impacts of development proposals on biodiversity values; assessment of effects of current fire management practices on biodiversity values; development of a more accurate assessment of the current reservation status of the sand plain vegetation types; better understanding of the conservation status of many species restricted to sand plain habitats; and greater understanding of the resilience of species and sand plain vegetation communities to impacts of climate change.

Future directions

- Complete isotopic signature data analysis in collaboration with Adelaide University and publish results.
- Locate additional long-term sampling plots on the SWATT in collaboration with the Terrestrial Ecosystems Research Networks' AusPlots Facility as funding permits.
- Complete analysis of metagenomic samples in conjunction with other transects in the Australian Transects Network.

Biological survey and conservation planning for the Swan Coastal Plain bioregion and adjacent scarps (Dandaragan, Darling and Whicher)

SP 2012-032

G Keighery

Context

The Swan Coastal bioregion is highly fragmented and impacted by settlement, urbanisation and industry. Detailed biological data at various levels is required to inform complex decisions on land use to conserve and protect biodiversity. This project delivers data for the Swan Coastal bioregion and adjacent scarps (Dandaragan, Darling and Whicher) to the relevant regulatory and statutory planning agencies, local government authorities and the community on the botanical values of uncleared land in the bioregion.

Aims

- Prepare a new 1: 250,000 vegetation complex map for the Swan Coastal Plain.
- Prepare reports and publications on conservation reserves and offset acquisitions (proposed and actual).
- With the help of volunteers, survey and report on areas of interest for conservation planning of the Perth region and greater Swan Coastal Plain IBRA region.

Progress

- Report completed describing vegetation complex mapping in the Bunbury to Busselton area.
- Digital map layer completed for 1:250,000 scale extension mapping of the Bunbury to Busselton area of the Swan Coastal Plain.
- Review paper on floristics of *Banksia* woodlands is in press.

Management implications

A better understanding of the conservation values of remnant and intact bushland areas forms the basis for improved land use planning and decision making for biodiversity conservation and natural resource management on the Swan Coastal Plain, including the Strategic Assessment of the Perth-Peel Region.

Future directions

- This project is now complete.

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 Great Western Woodlands, Indian Ocean Drive and central Pilbara to inform natural resource management and land use planning.
- Black spot flora survey of the Colville 1:100,000 map sheet.
- Resurvey of threatened claypan communities on the Swan Coastal Plain documenting 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

- Flora survey report of Colville 1:100,000 map sheet finalised and provided to Commonwealth Department of Environment and Energy.
- Fortescue valley claypan dataset has been analysed and a draft manuscript prepared.
- Floristic communities have been described for the Fortescue Marsh, these halophyte-dominated communities have been mapped for the Marsh Land System and a draft report completed.
- Flora survey of Mandora Marsh / Walyarta has been finalised and a draft 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 360,000 ha of mapping in the central Hamersley Range between Munjina and Weelumurra.
- A Pilbara AusPlots campaign established 19 plots in the Fortescue catchment between Millstream Chichester and Karijini National Parks. Plots were also established in the Kimberley and at Lowlands.

Management implications

- The survey of the Colville area has increased the flora known from this area 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 nationally threatened communities, as well as assisting 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 will inform environmental impact assessment processes associated with native vegetation clearing permits and major resource development proposals.This information will also provide information for fire management planning, particularly the development of burning prescriptions for Karijini National Park.

Future directions

Further surveys will be undertaken as required and when resources become available.

Western Australian terrestrial fauna surveys

SP 2011-021

M Cowan, L Gibson, A.H. Burbidge, D Pearson

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

- Colville 1:100,000 map sheet data have been digitised and the records submitted to the Department of the Environment and Energy.
- Peterswald 1:100,000 map sheet terrestrial vertebrate data have been compiled in a database.
- In April 2017 a survey of the area around Palm Pool, adjacent to the Fortescue River in the Millstream Chichester National Park was undertaken as an internal requirement for a Naturebank ecotourism proposal. The primary objective for this was to identify the presence of conservation significant fauna of which only two species were recorded. These were the Pilbara Olive Python (*Liasis olivaceus barroni*) and the Rainbow Bee-eater (*Merops ornatus*), with the former listed as vulnerable under both State and National legislation and the latter protected under international treaties for migratory birds. More than 100 DNA tissue samples were collected from the range of species caught during this survey. All data has been digitised and a report completed.
- In conjunction with regional staff, a survey was conducted at Kurarra Kurarra (ex-Earaheedy Station) using standardised methods for data and specimen collection. Data from this survey have been digitised, and

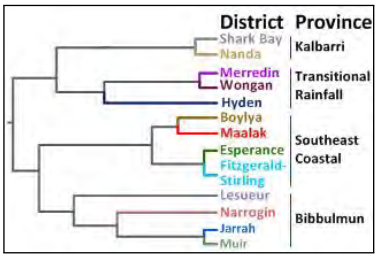
more than 30 voucher specimens and 200 tissue samples collected and lodged. A further 100 microbial samples were collected from vertebrates for collaborative work with Michigan University on the evolution of microbial diversity in reptile communities.

Management implications

The 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

- Upload Colville data to NatureMap and complete Peterswald vertebrate report.
- Black spot surveys will continue when timing is appropriate and field teams are available.
- Desktop assessment of the biodiversity values of abandoned mine shafts and proposed survey design.



Plant species richness and endemism within the south-western Australian Floristic Region

SP 2011-010

P Gioia

Context

The current departmental reserve acquisition and natural resource management process uses a range of inputs to help identify high priority areas with significant biodiversity values. Biodiversity indices, such as species endemism and richness, provide a valuable tool in this process. The department currently uses IBRA bioregional boundaries in a range of administrative and analytical contexts; however, IBRA boundaries have been identified as having a number of shortcomings when used to represent floristic diversity in Western Australia. A more ecologically appropriate set of boundaries is desirable.

Aims

- Generate and explore patterns of plant species richness and endemism at a range of scales for the whole flora of the south-western Australian Floristic Region using locality records for specimens in the Western Australian Herbarium.
- Develop a new phytogeographic map based on patterns of species richness and endemism.

Progress

- A manuscript describing a new phytogeographic map for the Southwest Australian Floristic Region was published in the *Botanical Journal of the Linnean Society*.
- Digital map and report products have been made available through NatureMap.

Management implications

- A floristically based regionalisation of the south-west will enable conservation planning to be based on ecologically meaningful boundaries that are founded on patterns of species richness and endemism.

Future directions
This project is now complete.

Kimberley islands biological survey

SP 2007-001

L Gibson, M Cowan, M Lyons, G Keighery

Context
Archipelagos along the Kimberley coast present an opportunity to conserve intact examples of ecosystems that have been modified or affected by various threatening processes on the Kimberley mainland. Knowledge is rudimentary about the distributions of species and ecological communities on the islands, including those species that are endemic to the Kimberley and those that are threatened on the mainland. Consequently, a comprehensive biological survey of the islands off the north Kimberley coast is required. This survey focuses on sampling vertebrate and selected groups of invertebrate fauna that are most likely to be affected by the cane toad, as well as by changes to other mainland selection processes. It will also sample the terrestrial flora, soil and other environmental attributes that are indicators of biogeographical patterning and environmental health, and that provide a basis for condition monitoring of the targeted survey islands.

Aims
- Build on existing knowledge of targeted components of biodiversity and determine the conservation status of islands off the north Kimberley coast.
- Identify locations of species that are susceptible to mainland threats, including cane toads, and identify the potential of islands as natural refuges.
- Provide baseline information for future ecological monitoring, evaluation and survey.
- Provide the knowledge base to underpin decisions involving conservation and development, including nature-based tourism, non-renewable resource extraction and infrastructure development.

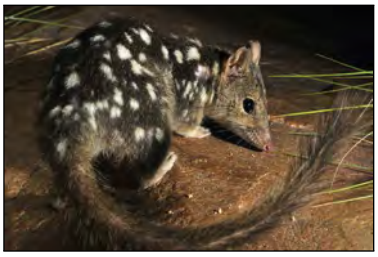
Progress
- Invited presentation given at a seminar series hosted by the Kimberley Society titled *Treasures revealed: a biodiversity survey of the Kimberley islands.*
- Book chapter accepted for publication in *Nature of the Kimberley* resulting from a seminar series hosted by the Kimberley Society.
- Paper describing biogeographic patterns in a multi-taxon framework on Kimberley islands accepted for publication in *Biological Conservation*.

Management implications
- Survey information provides a systematic foundation to support nature conservation planning for reserve system design, development and management, and for understanding the distribution and conservation status of species (indigenous and introduced) and ecological communities as a basis for their management.
- Survey information provides a baseline for long-term ecological monitoring.

Future directions
- This project is now complete.

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.



Improved fauna recovery in the Pilbara – Assessing the uptake of feral cat baits by northern quolls, and their associated survivorship

SP 2015-016

K Morris, J Angus, S Garretson, H Anderson, K Rayner

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, the project has entered phase two, the large scale implementation of *Eradicat*® baiting trials over 145 000 ha of Yarraloola on an annual basis until at least 2019. Monitoring programs will measure its success in reducing cat numbers and the recovery of priority species, including the northern quoll.

Aims

- Assess the field uptake of *Eradicat*® feral cat baits by northern quoll and impact on survivorship in the Pilbara.
- Develop an effective cat control strategy that will benefit the northern quoll and other threatened species in the Pilbara.

Progress

- A research permit was granted by Australian Pesticides and Veterinary Medicines Authority to aerial bait ~150 000 ha of Yarraloola with*Eradicat®* annually, until 2019.
- Sixty camera trap sites were set on both Yarraloola (baited) and Red Hill (reference site) for 25 nights both before and after baits were distributed to monitor feral cat occupancy.
- *Eradicat®* feral cat baiting of 144 000 ha area on Yarraloola was undertaken. Monitoring of individual *Eradicat®*baits using camera traps indicated few non-target species took these baits. Northern quolls did sample the occasional bait but learnt very rapidly to ignore them (i.e. become bait-shy). There was no evidence quolls were harmed by sampling toxic baits.
- Northern quoll populations were monitored at 18 trapping sites at both Yarraloola and Red Hill. Capture rates of quolls on both properties were equally low, with quolls continuing to survive and breed within the baited area with no apparent negative impacts.

Management implications

- The lack of impact of *Eradicat®* on northern quolls in the Pilbara has means that landscape control of feral cats using aerial baiting with *Eradicat®* can be used for feral cat management in areas where this species occurs in Northern Australia.
- Development of sound trapping methodology for monitoring northern quoll numbers in areas of relatively low abundance will improve monitoring of threat abatement programs.

Future directions

- The broadscale *Eradicat®* feral cat baiting program will continue over Yarraloola on an annual basis until at least 2019.
- Continue the use of camera traps in a before-after-control-impact (BACI) design to monitor the effect of *Eradicat®* baiting on feral cats at Yarraloola.
- Continue monitoring 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, 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. Dirk Hartog Island 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 Dirk Hartog Island 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

- Baiting for feral cats was completed in October 2016.
- Summer and autumn seasonal surveillance programs have been completed and no further cat activity has been recorded.
- Independent verification of the absence of cat activity south of the barrier fence was confirmed by detector dogs and their handlers in winter 2016. Monitoring north of the barrier fence commenced.

Management implications

- The biodiversity outcome from this project will be a measurable decline in the cat population on Dirk Hartog Island, eventually to zero when eradication is confirmed. This is essential before fauna reconstruction activities can commence. 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. Knowledge and technology transfer to other agencies contemplating cat eradications on islands will be through presentations and publication of manuscripts in scientific journals.

Future directions

- Verify absence of cats using independent techniques (detector dogs).
- Undertake seasonal surveillance monitoring for cat presence across the island and instigate immediate control effort if detected.
- Draft a series of manuscripts for publication relevant to the overall program and techniques developed.

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

SP 2013-005

N Thomas, M Cowan, B MacMahon, S Garretson

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 Parks and Wildlife 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 a number of 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. In particular, 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 mammals species in the south-west of Western Australia.
- Investigate the effectiveness of baited (active) and un-baited (passive) cameras sets to inventory targeted species.
- Investigate and assess the most appropriate methods of image analysis and data storage.

Progress

- Methods and data from this project have been utilised in the South West Fauna Recovery Project (Dryandra). Summaries of detection rates and spatial patterns for all critical weight range mammals and larger species within the primary Dryandra block for 2014 to 2017 have been provided to the South West Fauna Recovery Project team.
- A Science and Conservation Information Sheet on assessing camera traps to census mammals has been prepared.
- A Microsoft Access database, CPW Photowarehouse (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 camera.
- 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.

Management implications

- 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 cameras capacity to be triggered and thus detection rates may be affected.
- 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.
- 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 analysis of data.
- Reconyx camera traps (models HC600 and PC900) are considered to be among the most effective commercially available camera traps for departmental requirements and currently remain recommended for use. It should be noted however that technology is constantly changing in this field and improvements in performance and price are likely in the future. Differences in performance though may have considerable ramifications for comparative data where camera models change over time.

Future directions

A publication on the use of camera traps as a survey and monitoring tool will be prepared.

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

SP 2013-001

C Lohr, K Morris, L Gibson

Context

The goal of this project is to prioritise island management actions such that we maximise the number of achievable conservation outcomes for island biodiversity in the face of threats from invasive species. Western Australia has over 3700 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 initially 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 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 BBN software).

Progress

- Version 3 of the Islands DSS was presented to Parks and Wildlife staff and external researchers at a dedicated symposium and workshop at the Ecological Society of Australia conference, November 2016.
- Islands DSS graphical user interface and functionality is being tested, and user manual is being drafted.
- Biosecurity BBN software is complete, case study is published in *Science of the Total Environment*, and user manual is being reviewed.
- Pilbara island species occurrence database is published on NatureMap. Historical data has been entered and new data from Pilbara regional staff is being regularly entered. Species demographic attributes and interactions database is being combined with the Pilbara island species occurrence database.
- Cost and efficacy of management actions database is under development.
- Pilbara islands habitat map is being validated using independent botanical surveys of five islands.
- Presentations were made at Island Arks Symposium III, Australasian Wildlife Management Society, 27th International Congress for Conservation Biology, 7th Annual Conference of the Australasian Bayesian Network Society, 30th Association for the Advancement of Artificial Intelligence Conference, the Ecological Society of Australia 2016, the Pilbara Marine Conservation Program symposium, and the Chevron Environmental seminar.

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

- Finalise and publish Island DSS and Biosecurity BBN software, and user manuals.
- Store software input files on Departmental online data catalogue.
- Use Islands DSS to draft an initial set of management priorities for Pilbara islands.
- Use Biosecurity BBN software to identify island surveillance priorities.

Conservation and management of the bilby (*Macrotis lagotis*) in the Pilbara

SP 2012-035

M Dziminski, K Morris, 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 data set of bilby records in the Pilbara continues to be collated from existing sources and field surveys. Bilbies in the Pilbara were found to be associated with stands of particular plant species, especially some *Acacias* that provide the major food resource in the form of cossid moth larvae (grubs) from their root systems.
- Preliminary distribution modelling identified soil type and depth, and elevation as major relative contributing variables to predict likely bilby habitat.
- The type of sign that can be used to confirm the presence of the bilby in comparison to sign that should only be used to flag potential presence was described. A protocol to assess potential activity and verify bilby presence and a sampling technique was outlined.
- A set of interim guidelines for occupancy surveys and surveys to detect the presence or absence of bilbies, and assess the importance of habitat, was developed to promote standardisation and comparability. These interim guidelines are based on best practice techniques used nationally and form a template to be reviewed by researchers, consultants and traditional owner rangers.
- A study on detectability of bilby sign from remotely piloted aircraft (RPA) showed altitude and speed had significant effects on the proportion of bilby diggings detected, and it was found that an altitude of 12 m at 6-8 km/h resulted in increased detection rates. A number of other variables need to be examined including different vegetation types and lighting conditions.
- A study of the effect of storage technique for bilby scats on DNA degradation found no difference in amplification or error rates between dried or frozen samples. Storing samples dry is more practical in the field, and it is recommended that samples are stored and transported in tubes with silica gel beads and cotton wool to protect the sample.
- The population abundance monitoring technique using DNA extracted from scats quantitatively collected at populations in the field continues to be implemented.
- Parks and Wildlife sponsored the Ninu (Bilby) Festival that was held at Kiwirrkurra in the Gibson Desert. The festival was hosted by the Kiwirrkurra Rangers, Kiwirrkurra Community and facilitated by Central Desert Native Title Services.

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.
- This work has found that populations in the Pilbara are geographically isolated and consist of a small number of individuals. This means that 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 any surveys using RPA require ground-truthing of both positive and no 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, K Morris, 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)
- Assess genetic diversity, genetic structure and cave use of ghost bat (*Macroderma gigas*) populations in the Pilbara

Progress

- Initial mt DNA sequencing of *I. obesulus*, *I. auratus*and *I. macrourus* was insufficient to fully resolve taxonomic issues and genomic analyses is being undertaken. 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 exploring the long-term trajectory of populations with and without fauna underpasses, and with an additional range of threats (fire, urban expansion, inbreeding). A manuscript has been prepared for submission 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 rock wallaby populations has been completed. Further genetic and population viability analyses of recent translocations to Kalbarri National Park are being undertaken.
- DNA barcoding was used to identify two stranded cetaceans.
- Genetic diversity of translocated brushtail possums was compared with the source populations showing that genetic diversity has been maintained through mixing of source populations in translocated founders. A population viability analysis model has been developed. A draft scientific manuscript is currently in preparation.
- DNA extractions have been completed for ghost bat scat samples and microsatellite genotyping is underway. Additional new microsatellites developed for the species are currently being assessed for variability.

Management implications

- An Australia-wide phylogenetic assessment of *I. 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 on evaluation of threat status by the Commonwealth for the eastern and Tasmanian sub-species of *I. obesulus*.
- Genetic and population viability analysis showed that quenda populations in small, isolated patches of remnant vegetation in the urban matrix are vulnerable to genetic erosion, inbreeding and population decline, particularly when connectivity within (fauna underpasses) or between (increased urbanisation) habitat patches is inhibited. 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 2016-7 translocation of rock wallabies to Kalbarri National Park will inform whether further supplementation is required and help predict their future success.
- Genetic analyses and PVA of brushtail possums at Matuwa showed that augmentation is required to maintain genetic diversity.

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 population viability manuscript will be submitted and the mating system manuscript finalised.
- Comparison of historic and contemporary population genetics of wheatbelt rock wallaby populations will be undertaken to monitor genetic change and investigate impact of past management actions. Analyses of genetic diversity and population viability of Kalbarri National Park translocated rock wallaby populations will be completed.

- Brushtail possum manuscript will be finalised.
- Genetic data analyses will be completed for ghost bat populations, including assessment of population structure, genetic diversity, relatedness and effective population size.

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

SP 2012-033

K Ottewell, M Byrne, K Morris

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.

Aims

- 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.
- Determine genetic diversity and gene flow amongst quenda (*Isoodon obesulus* ssp. *fusciventer*) populations in fragmented and continuous populations in the Perth region, in reserves of varying size and connectivity.
- Identify habitat features that are associated with high genetic diversity and gene flow in quenda populations using GIS and habitat modelling, and how well these features are captured in the reserve system.
- Assess the genetic diversity and genetic structure of target 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 quenda populations distributed through the Perth Hills and Swan Coastal Plain regions. Analyses identified four population clusters. Areas that were 'hot spots' and 'cold spots' of genetic diversity and connectivity were found, and will be used to inform future management. Results were presented at the Ecological Society of Australia meeting and a draft manuscript is well progressed.
- Landscape genetic and habitat modelling analyses are underway for quenda. Analyses have identified habitat and non-habitat variables important for connectivity among quenda populations and a draft manuscript is in preparation.
- Genetic diversity, connectivity and habitat modelling analyses have been completed for three target small mammal species in the Pilbara and a draft manuscript is in preparation.

Management implications

- Adequacy of the current reserve system in conserving species genetic diversity and genetic processes, such as gene flow, will provide insight into genetic patterns in Western Australian landscapes and how these patterns have been shaped through species' responses to climate and landscape features. Species-specific recommendations will also be made to guide translocations and help prioritise conservation management activities.

Future directions

- Genetic connectivity and habitat modelling analyses will be finalised for the quenda study, manuscripts submitted and management recommendations provided.
- The draft manuscript on the Pilbara mammal species will be finalised and submitted.

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

SP 2012-024

C Sims, M Blythman, K Morris, N Burrows

Context

Operation Rangelands Restoration commenced in 2000 with the acquisition of Lorna Glen and Earaheedy pastoral leases by the Western Australian Government. This 600,000 ha area lying across the Gascoyne and Murchison IBRA regions 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 Lorna Glen (Matuwa) and Earaheedy (Kurrara Kurrara).

The area around Lorna Glen 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 1100 ha introduced predator proof fenced enclosure. The intention is to use these as a source for translocations to areas of Lorna Glen 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 Lorna Glen 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.
- Study 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.
- Development of broad camera trap system to identify threatened fauna and predator activity across landscape has been completed. Successful *Eradicat*® baiting in 2016 resulted in a ~50-60% reduction in cat numbers across the property, as demonstrated by Camera trap transects on roads.
- Ongoing monitoring of bodies and bandicoots inside the enclosure indicates good population numbers and reproductive rates. Golden bandicoot capture rates are still reduced since the 2015 release, and may be related to high captures and interference of boodies excluding new recruit bandicoots from accessing traps.
- Ongoing presence and sightings of mala adults and juveniles were detected inside the enclosure.

- Presence of golden bandicoots at release sites from the 2015 reintroduction has declined significantly in last 12 months in absence of ongoing intensive predator management. However, persistence of at least one original founder ~ 20 months post release, and record of juvenile animals at other locations, indicates the possibility that a scattered low density population is still present.
- A novel method (metal detectors) to find and identify threatened fauna as prey items in Wedge tail eagle diet, through finding individual Passive Integrated Transponders (PITs), has been developed.

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. brush tail possums).

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.
- Develop plan for translocation of boodies outside enclosure in 2018. Likely to include experimental field trial of comparative survival between predator 'trained' and 'untrained' boodies in cooperation with Arid Recovery Project.
- Respond to ongoing presence of low density bandicoot population outside the fenced enclosure, with targeted small scale reinforcement.

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 has been completed and analysis of data is under way.
- Trials to measure the rate of survival of red-tailed phascogales demonstrated a high survival rate although cameras showed that phascogales were interested in the baits.
- The red-tailed phascogale *Eradicat®* uptake data is currently being analysed and publication prepared.

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

- Assess the effectiveness of setting leg-hold traps in raised sites (buckets of sand) for cats to reduce non-target capture in Dryandra Woodland.
- Cats will be captured and fitted with GPS collars to determine their survival through an *Eradicat®* baiting event to determine the effectiveness of this control method.

Conservation of south coast threatened birds

SP 2012-022

A.H. Burbidge

Context

Identifying the conservation requirements of threatened south coast birds, such as the Critically Endangered western ground parrot, the Vulnerable western bristlebird, and the western subspecies of the western whipbird, will aid *in situ* management of these taxa. Understanding responses to fire, biological and behavioural characteristics, such as vulnerability to predation, and nesting site requirements are essential knowledge for the conservation of these Western Australian endemics birds 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.

Progress

- Monitoring of western ground parrots after extensive fires in Cape Arid National Park and Nuytsland Nature Reserve continued.
- Ground parrot monitoring protocols are being further refined through use of audio recordings and analysis of trends in current data set.

- Genetic analysis of western whipbird phylogeny has been published online. Clarification of the taxonomic status of individual populations indicated a clear separation between eastern and western Australian populations, but little variation within the west, supporting the hypothesis that all Western Australian populations belong to one subspecies, not two as previously thought. This conclusion is being incorporated into formal conservation status listing of whipbirds (i.e no longer eligible for listing).
- Assisted in overseeing the management of the captive western ground parrot program at Perth Zoo.
- Assisted in finalising reporting on western ground parrot workshop, dissemination of report, and initiation of action on recommendations.
- Assisted in finalising the recovery plan for the Australasian bittern in Western Australia.

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 of introduced predators and fire, in important conservation reserves on the south coast.

Future directions

- Finalise writing up of data on response to fire by bristlebirds and write up data on morphometrics of the western ground parrot.
- Assist in implementation of further field-scale feral cat control (with monitoring) in key western ground parrot habitat within the South Coast Region.
- Continue to develop monitoring analyses and techniques, and finish writing up recent survey data.

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

- The third season of regional northern quoll monitoring at ten sites was undertaken.
- Predictive species distribution modelling was undertaken in collaboration with Edith Cowan University. Distribution maps have been produced, and expanded to include scenarios of climate change and cane toad invasion.
- Northern quoll distribution model paper has been published in *Nature Conservation*.
- Research priorities for the Pilbara northern quoll (as determined by 2013 workshop) were published in *Australian Mammalogy.*
- A third northern quoll workshop was hosted by Parks and Wildlife with support from Roy Hill.
- Quoll distributional data continued to be added to the Pilbara Threatened Species portal in NatureMap.
- Dietary analysis was undertaken on 500 northern quoll scats from throughout the Pilbara, and a paper was published in *Journal of Mammalogy*.
- Northern quoll spatial use and home range estimates were generated from an Honours project in association with Edith Cowan University.
- Novel GPS collars for northern quolls were tested in a field setting, and provided information on spatial use and interactions with infrastructure.

Management implications

- Enhanced distributional data that is publicly availability 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-practise 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

- Completed surveys and monitoring of graceful sun-moth populations in February and March 2017.
- Commenced analysis of results for final report

Management implications

- Information on the distribution, abundance and habitat requirements of the graceful sun-moth has enabled the conservation status of the species to be downgraded from Vulnerable to a non-threatened status (Priority 4). Monitoring will be continued until 2017 to ensure that the population is stable and to confirm the appropriateness of its current conservation listing.

Future directions

- Further examination of hybrid populations between the coastal graceful sun-moth (*S. gratiosa*) and inland claret sun-moth (*S. jcaria*).
- 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 it appears little can be done to prevent their spread across the landscape. Previous work has identified that predators, such as northern quolls and goannas, are especially vulnerable to poisoning by toads. Research will focus on using taste aversion training to mitigate the impact of cane toads on wild northern quoll and goannas. Monitoring of northern quoll and goanna populations on islands will provide data to understand how these species respond to the recent arrival of toads on islands.

Aims

- Refine methods to field test taste aversion training, especially with northern quolls, goannas and snakes.
- Develop techniques to roll out taste aversion training on a landscape basis should it be successful in inducing predators not to eat toads.

- Monitor quoll and goanna populations on the recently toad infested Adolphus Island to understand if these populations will persist.
- 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

- Trials of mass produced taste aversion sausages aimed at teaching quolls to avoid toads were undertaken in Mitchell River National Park in early 2017. Data and camera images are currently being analysed.
- Surveys and camera arrays have been maintained on Adolphus Island to monitor quoll and goannas populations following the arrival of toads on the island. Monitoring shows quolls and goannas have persisted on Adolphus Island in the presence of cane toads.
- 20 cane toads were fitted with radio-transmitters to determine where they survive during the dry season.

Management implications

- Taste aversion training using toad sausages laced with a nausea-inducing chemical or “teacher toads” may lead to short term taste aversion in the northern quoll. If longer taste aversion is demonstrated, this will be a valuable technique to protect island populations of quolls and other toad-susceptible species.
- Trials of mass-produced conditioned taste aversion sausages made at the Department’s Harvey bait factory will allow assessment of the most cost-effective way to preserve predator populations on a landscape scale across the Kimberley.

Future directions

- Investigate where cane toads survive over the dry season to understand how they are likely to impact island populations and to assess the likely effectiveness of a “waterless barrier” proposed by some academics to stop toads spreading from the Kimberley into the Pilbara.
- Further trialling of taste aversion baits will examine how long predators are able to remember their taste aversion training, improving their resilience to be dropped from an aircraft and whether other forms of taste aversion can be used to prevent declines in reptiles due to toad invasions.

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

- Analysis of bait composition continues with the objective of further improving 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 these compounds is being assessed in bait uptake trials. Modification of the bait production facility is to occur in the near future, which will allow further improvement to bait palatability and longevity in the field.
- The five-year feral cat baiting programs on the Fortescue Marsh has been completed. All campaigns have resulted in statistically significant declines in cat occupancy rates in the baiting area. Recommendations for future baiting programs to maximise effectiveness have been submitted and a manuscript reporting the work has been submitted for publication.
- Effectiveness of seasonal baiting strategies is continuing to be assessed under the temperate climatic conditions of the south-west at sites including Cape Arid and Fitzgerald River National Parks. The program involves the assessment of baiting effectiveness in autumn, winter and spring to provide the optimal baiting strategy for this region.
- Stage 1 of the management plan for the control of cats on Christmas Island has been completed with all domestic cats now desexed, microchipped and registered. Stage 2 of the plan is continuing and involves the removal of all stray/feral cats from residential areas and surrounds. Stage 3 of the plan, island-wide eradication of feral cats, is underway and control efforts will continue until 2020 prior to a surveillance period to confirm eradication success.
- An encapsulated 1080 toxin bait (*Hisstory*) is being tested this year in the Kimberley as a baiting option where non-target species may be considered at risk from the 1080 direct injected *Eradicat*® baits.
- Work continues on improving and refining cat lure options. A collaborative project is being undertaken with Phillip Island Nature Park (Victoria) to investigating visitation and re-visitation rates to audio lure and 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 investigation of 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 (*Potorous gilbertii*) recovery plan

SP 1996-008

A Friend, S Hill, T Button

Context

Gilbert's potoroo is the world's rarest marsupial. The *Gilbert's Potoroo Recovery Plan 2003-2008* provides a list of actions to improve the conservation status of this Critically Endangered species. This project involves,

or has involved collaborative arrangements with, Parks and Wildlife South Coast and Warren Regions, South Coast NRM, universities (The University of Western Australia, Murdoch, Edith Cowan and Adelaide), the Royal Zoological Society of South Australia, the Foundation for Australia's Most Endangered Species (FAME), private sponsors and the Albany-based Gilbert's Potoroo Action Group to implement conservation actions.

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

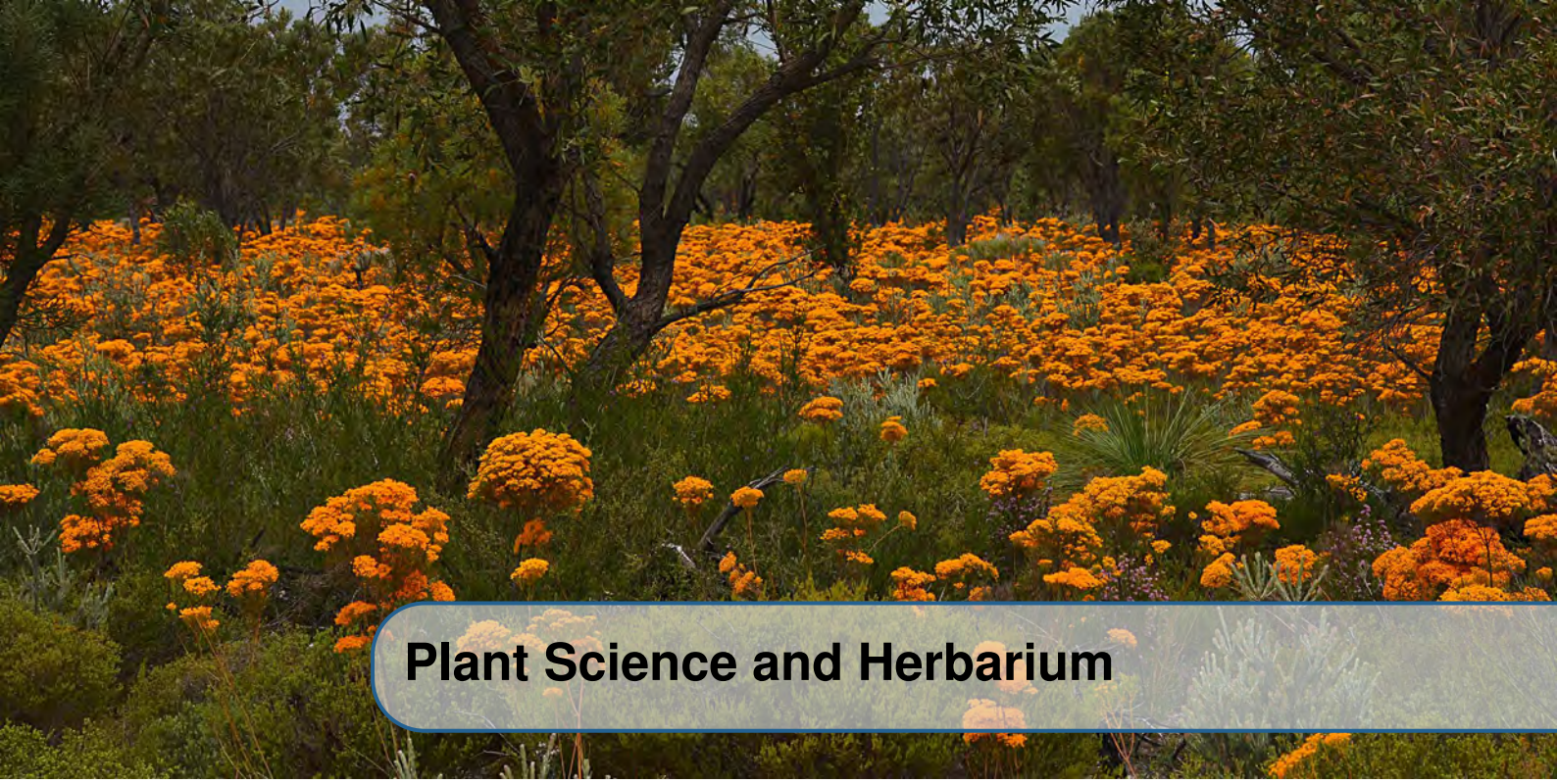
- The updated Recovery Plan for Gilbert's Potoroo was given endorsement at the State level in September 2016. It is now awaiting endorsement by the Minister for the Environment and Energy.
- The suitability of Michaelmas Island as a haven for the small group of potoroos rescued from Mount Gardner after the catastrophic wildfire of November 2015 was investigated. Initial habitat assessment gave promising results but when four of the rescued potoroos were released on the island in July 2016 it became clear that insufficient food was present. Census trapping of other populations revealed 15-20 animals in the Waychinicup enclosure and five at Two Peoples Bay.
- Assessment of Middle Island in the Recherche Archipelago as a translocation site is being undertaken.

Management implications

- The establishment of two insurance populations under the Recovery Program 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.
- Use of python management techniques in the Waychinicup enclosure is required to reduce predation on potoroos by carpet pythons.
- 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.

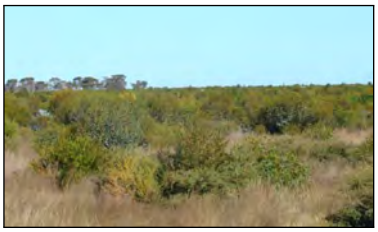
Future directions

- Underatake analysis and publication of potoroo population demographics to determine future monitoring needs at all sites.
- Evaluate Middle Island (Recherche Archipelago) for suitability as a translocation site for Gilbert's potoroo utilising surveys for fungi and nesting habitat and implementing trial translocations.



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 and other research institutions 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 the 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.



Is restoration working? An ecological genetic assessment

SP 2016-015

D Coates, M Byrne, M Millar

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, Acacia cyclops*, and are in progress for *Eucalyptus occidentalis*.
- Analysis of insect visitors, seed viability, genetic diversity and mating systems has been completed for *H. laurina* in restored and remnant populations.
- Genotyping of leaf and seedling material is being undertaken for *H. nitida, M. acuminata, B. media and A. cyclops*.

Management implications

This project will provide practical recommendations on how the ecological and genetic viability of restored populations may be affected by different establishment regimes.

Future directions

- Field work collecting leaf and seed material, and mapping individuals of *E. occidentalis* will be completed.
- Genetic and mating system studies will be completed for the remaining four target species.
- Evaluation of the affect of restoration age on the mating system and reproductive performance of the target species will be undertaken.

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

- A paper on *Hypocalymma* has been submitted to *Nuytsia*.
- Papers on *Anticoryne, Rinzia* and *Scholtzia* (Myrtaceae) and *Isopogon* (Proteaceae) have been published in *Nuytsia*.
- Papers on a new subtribal classification of Chamelaucieae and on *Hysterobaeckea* 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

- Continue progress towards an official release of the interactive key through publication of an introductory paper in *Nuytsia*.
- Submit papers on *Hysterobaeckea, Scholtzia* and the new subtribal classification (Myrtaceae).
- Begin the preparation of 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 submitted for publication with scientific journals.

Management implications

Under projected warmer and drier climates for the region 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 genus *Wadithamnus* and new species of *Eremophila* and *Nymphoides* have been published in *Nuytsia*.
- Paper describing a new species of *Chamaescilla* has been submitted.
- Article was submitted to *Landscope* magazine (winter edition).
- NatureBank survey and report have been completed for proposed development in Millstream-Chichester National park.
- A paper synonymising *Ptilotus* taxa has been published in *Nuytsia*.
- Key to Australian and Western Australian *Ptilotus* was published on Keybase.

Management implications
- Clarifying the taxonomy and identification of *Ptilotus*, *Gomphrena* and *Swainsona* is important as these genera include indicator species and are significant for rangeland and arid land management and assessment. Many species are annuals, and *Swainsona* is a nitrogen-fixing legume. Some species of *Ptilotus* have been shown to have high phosphate uptake capabilities and are potentially useful in rehabilitation. 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, 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 Parks and Wildlife processes and datasets, including the Threatened and Priority Flora databases maintained by the Species and Communities Branch, 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

- 303 plant names (281 formally published and 22 informal names) were added to WACensus.
- 1249 other edits were made to the WACensus.
- WACensus updates were regularly distributed to 252 registered Max users.
- Name changes in the APC were reviewed for the Federal *EPBC Act* list of Threatened flora and communicated the state viewpoint in discussions on APC updates.
- Annual records of changes to WACensus were published in *Nuytsia*.
- The national plant names database was edited for taxonomic changes relevant to Western Australia.

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 Australia information to national biodiversity systems such as the Atlas of Living Australia, the Australian Plant Census (National Species List) and the Australasian Virtual Herbarium.

Future directions

- Provide a comprehensive and up to date census across all plant groups.
- Finalise modifications based on the globally accepted list of families and family circumscriptions of the Angiosperm Phylogeny Group (APG) IV (2016) and APC.

The Western Australian Herbarium's specimen database

CF 2011-110

J Percy-Bower, K Knight, M Falconer, E McGough, E Wood-Ward

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 Parks and Wildlife 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 Australian 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 Parks and Wildlife decision support systems and research.

Progress

- 11,382 records were added to WAHerb, including 1059 Priority Flora, 138 Threatened Flora and 3 Presumed Extinct Flora. The following projects and significant collections were databased: Pilbara Biological Survey, Desert Discovery, Kimberley Islands Biodiversity Survey.
- Regularly provided customised specimen data requests (species lists and label data) to Parks and Wildlife officers, researchers and the public.
- 87,916 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 update and valid plant species names.

Future directions

- 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 McGough, E Wood-Ward, M Hislop, R Davis

Context

The Western Australian Herbarium's 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 Parks and Wildlife and the community with the fundamental resource providing 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 Parks and Wildlife.
- Contribute to, support and service taxonomic research by the world's scientific community.

Progress

- 11,382 specimens were added to the collection, which now stands at 779,638, a 1.5% increase in holdings during this period.
- Loans and exchange: loans outward–15 loans consisting of 636 specimens; loans inward–10 loans consisting of 402 specimens; loans returned to the Herbarium–26 loans consisting of 837 specimens; loans returned to their home institution–20 loans consisting of 3901 specimens; exchange inward–798 specimens; exchange outward–920 specimens including 15 requests for destructive sampling.
- Tasks managed by Collections staff with the assistance of volunteers were as follows: mounting and labelling 8479 specimens; validating the name and occurrence of 1419 incoming specimens for lodgement; curating the backlog of algae; curating the microscope slide collection.
- The most significant projects accomplished were the physical expansion of the research collection to ensure the safety and future protection of each specimen; and the rehousing of the spirit collection.
- Volunteer participation was significant, totalling 9690 hours, which is equivalent to ca. 5.6 full time employees.
- Maintained the Reference Herbarium facility, which has 14,931 specimens representing 11,769 taxa and also added or replaced 71 specimens. 1216 visitors used this resource to identify plant specimens during this period.
- Research Collection was accessed by 935 visitors to study taxa or help with identification.
- Provided 155 high resolution scans of herbarium specimens to Parks and Wildlife 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.
- Significant collections were lodged included industry surveys, regional Parks and Wildlife staff surveys, South Western Australian Transitional Transect, Pilbara Biological Survey, M & R Barrett, G & R Byrne, Desert Discovery and Bushblitz.
- 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 Parks and Wildlife, other government agencies, environmental consultancies, regional herbaria and the public. Significant projects requiring identification services this year included Bushblitz, Desert Discovery and AusPlots.
- Educational role continued with staff providing tours of the Herbarium for tertiary institutions, Parks and Wildlife staff, environmental consultancies, community groups and the media.
- Scanned 110 Types for the Global Plants Initiative where Western Australian Herbarium Type specimens are now accessible to the world's scientific community for study.

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 Parks and Wildlife 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 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 research collection.

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 780,000 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 over 65,000 images.

Aims

- Deliver authoritative taxon, specimen and image information on all Western Australian plants, algae and fungi 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

- FloraBase, WAHerb, Imagebank and BioCASE were migrated to new hardware as part of a complete overhaul of the Western Australian Herbarium's IT infrastructure.
- Maintenance of FloraBase content continued, including an enhanced browse mode that includes the non-vascular flora, support for a major upgrade of Proteaceae keys to the latest version of Lucid, and their use in FloraBase, regular *Nuytsia* sub-site updates to support ongoing journal releases, updated flora statistics page; and 13 other bug fixes for FloraBase.
- Maintenance of WAHerb continued, including a major overhaul to the way specimen labels are generated, and 36 bug fixes for the Publishing System and WAHerb projects.

Management implications

- FloraBase allows the community and Department staff to retrieve the most recent information on the name, features, status and distribution of the 13,827 currently recognised native and naturalised Western Australian vascular plant 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, AVH, the ALA generally 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.
- 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 interactive keys (eFlora) for identification of plant groups to species level.
- Complete and release the Specimen Accessioning Tool after a testing phase.
- Upgrade WAHerb to full Unicode support (Texpress 9).
- Develop further standards to facilitate and participate in national and international bio-infrastructure projects, such as ALA, NatureMap and other common 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. What this will mean for the West Australian epacrid flora is that all taxa 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 describing six new species of *Leucopogon s. str.* (including two of conservation significance) from the Geraldton Sandplains was published in *Nuytsia*.
- A collaborative paper with descriptions of five new species (including three of conservation significance, one Threatened Flora) of *Styphelia* (in the new revised sense) from the Geraldton Sandplains was published in *Nuytsia*.
- A Short Communication transferring *Conostephium pungens* to the recently reinstated genus *Stenanthera* was published in *Nuytsia*.

- A paper updating the taxonomy of the genus *Brachyloma* has been submitted to *Nuytsia*.
- A collaborative nomenclatural paper is well advanced, in which the transfer to *Styphelia* of species currently in *Leucopogon, Astroloma, Coleanthera* and *Croninia,* will be formalised.
- A paper dealing with the taxonomy of one natural group of western *Styphelia* is well advanced.

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*.

Taxonomic studies on native and naturalised plants of Western Australia arising from biological survey

SP 2011-013

G Keighery

Context

Many Declared Rare Flora have nomenclatural and taxonomic issues that require resolution for their conservation and management. Many new taxa are routinely uncovered during biological survey and require taxonomic description and conservation assessment. Correct identification and recording of weeds are a major issue for biodiversity conservation.

Aims

- Provide informative, stable taxonomy of potentially conservation-dependent taxa to aid their conservation and management, especially rare flora.
- Ensure that new taxa discovered during biological surveys are curated and described where possible. Studies are being undertaken on *Adenanthos pungens*, *Calytrix breviseta*, *Hypocalymma angustifolum*, *Adenathos eyeri - A. forrestii - A. ileticos* species complex, *Cynoglossum*, *Grevillea curviloba* and *Grevillea evanescens*.
- Update weed data for collections in the Western Australian Herbarium.

Progress

- Papers on the status of *Senecio diaschides*, *S. condylus* and *Hisiopteris* were published in Nuytsia.
- Three new prohibited Category 1 Declared weeds (C1) recorded for Western Australia (*Geissorhiza aspera*, *Calyptocarpus vialis* and *Ranunculus repens*).
- 12 new naturalised plants were added to Census of Western Australian Plants database (WACensus).
- Papers on adding / deleting weeds for Western Australia are in press in *Nuytsia*.
- Papers on weeds on all west coast offshore islands were published in *Nuytsia*.
- Papers on *Grevillea curviloba* and the taxonomy of *Calytrix* are in press in *Nuytsia*.
- A new Declared Rare Flora species and a Presumed extinct species were recommended for addition to the Wildlife Conservation (Rare Flora) Notice of Threatened Flora.

Management implications

The clarification of native and/or naturalised status of several species leads to better allocation of resources for managing weeds.

Future directions

- Publish a paper on the procedural systems for adding and deleting naturalised plants from the WACensus.
- Complete drafting descriptions for 25 new *Darwinia* species.
- Submit a paper on the *Hypocalymma angustifolium* complex.

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

SP 2011-002

R Butcher

Context

Tephrosia is a large, pantropical legume genus comprising *c.* 400 species of herbs and shrubs. Sixty-two taxa are currently recognised in the Eremaean and Northern Botanical Provinces of Western Australia; including 29 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 using morphological and molecular approaches.
- Assess the conservation status of all Western Australian taxa.
- Prepare identification tools, including an electronic key to the genus.

Progress

- A final report was completed and submitted to Rio Tinto Pty Ltd. giving detailed descriptions and discussions of distribution, habitat and taxonomic affinities for all informally named species (26) in Western Australia, and diagnostic descriptions for all informally named infrataxa (3) and species re-circumscribed as a result of this research (3). Detailed accounts of variation in the three most problematic complexes were also presented, as were the results of a morphometric study on the orange-flowered '*T. supina* complex' segregate taxa.
- A series of papers formally describing new species of *Tephrosia* in the Eremaean and Northern Botanical Provinces of Western Australia are in preparation.
- 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.
- An Australian Biological Resources Study (ABRS) National Taxonomy Research Grant Programme (NTRGP) three-year research grant was successfully obtained for further work on *Tephrosia* in Western Australian and the Northern Territory.

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 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* (AVH), 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 Kimberley (WA).
- 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

- *Lepilaena*(Potamogetonaceae; to be re-named *Althenia*): a genus of aquatic plants that has been difficult to identify has been studied from all Australian herbarium specimen holdings and species boundaries have been defined. Paper for one new Western Australia species has been submitted. Presentations on pollen structure and variation, and the morphology of the plants were given at a conference. Work has continued on specimen study and field work for a revision of the genus. Preliminary results of DNA analysis for a phylogeny have been obtained.
- *Wurmbea* (Colchicaceae): Paper preparation for describing thirty new species continued. A paper was published in *Phytotaxa* on the status of a species in New Zealand.
- Hydatellaceae: paper prepared on molecular phylogeny and genetic variation in *Trithuria australis,* but knowledge gaps identified require further field work. Morphological variation is being studied in *T. bibracteata*.
- Poaceae: continuing research collaboration on *Neurachne* and the evolution of C_4 photosynthesis. Paper published in *Plant Physiology* on chloroplast enzyme evolution in *Neurachne* species. Paper in preparation reporting the discovery of an unusual virus genetic signature in *N. minor*.
- *Thysanotus*(Asparagaceae): Review of the taxonomy of the twining species, the *T. patersonii* group, continued, with further field work that revealed two previously unknown species. Species definition

continued using collections and photos made during the project, and preliminary results were obtained from the DNA analysis. A paper was published in *Nuytsia*transferring *Murchisonia* to *Thysanotus*.
- *Lomandra* (Asparagaceae): paper being drafted on *L. suaveolens* group.
- Asparagales: paper on a neglected taxonomically useful flower feature in several plant families is in press. Collaboration has commenced on a wider, Melbourne-based, phylogenetic study of the Asparagales order of families. Discussions and plant samples have been contributed.

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 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 published in *Seed Science Research* describing effects of temperature on germination of 26 rare, common and geographically restricted Western Australian *Eucalyptus* species in the context of global warming.
- Paper published in *Australian Journal of Botany* describing the impact of long duration, temperature fluctuations on overcoming seed dormancy in four common Western Australia *Acacia* species.

- Experiment completed assessing the impact of long duration, temperature fluctuations on overcoming seed dormancy in a threatened *Acacia* species from the Stirling Range National Park.
- Continued assessment of the temperature niche for germination in species from the south west of Western Australia focusing on endemic species.

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

- Draft and submit a paper on the influence of long duration temperature fluctuations on overcoming dormancy in a threatened Western Australian *Acacia* species.
- Ongoing studies profiling the temperature niche for germination of a range of Western Australian species.

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 identification guide and readily accessible diagnostic information for the known species in Western Australia, which hinders accurate identification by conservation personnel, botanical consultants and other stakeholders. This is concerning given 98 Western Australian taxa are conservation-listed, the majority of which require further survey to understand the full extent of their distribution.

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

- A paper resolving a range of typification issues was published in *Nuytsia*—this information will feed directly into the *Australian Plant Name Index* and *eFlora of Australia* treatment of Stylidiaceae.
- Descriptive data was compiled for a range of species through herbarium-based research—these data will underpin future research papers and identification guides.
- The identity of more than 400 herbarium specimens of Western Australian origin was confirmed or corrected at the Western Australian Herbarium and Queensland Herbarium.
- Populations of *Stylidium asymmetricum* were surveyed in collaboration with staff from Perth Hills District and a Threatened Flora nomination prepared.
- A revised classification of *Stylidium* has been progressed using phylogenetic data generated by collaborators at the Royal Botanic Gardens, Kew.

Management implications

Taxonomic research and targeted field work has improved our understanding of the distribution, habitat requirements and conservation status of a range of triggerplant species, thus enabling effective conservation management of these species.

Future directions

- Prepare taxonomic papers on focus groups, conducting targeted field work as needed.
- Progress phylogenetic research papers and identification guides.

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 strategy. 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 submitted and will be published by Australian Biological Recourse Study and CSIRO Publishing. The book will be a major contribution, with over 1350 figures (many in colour) and descriptions of several hundred species, over 70 of which are new to science.
- Participation in a field survey to Coral Bay, resulted in numerous new collections that have added several hundred specimens to the herbarium holdings. These collections included specimens that formed the basis of the new genus *Leiomenia* (Kallymeniaceae).
- Several additional major papers have been published describing aspects of the Western Australian marine flora, including a major revision of the family Kallymeniaceae that resulted in the description of 10 new genera, 10 new species, and the generic reassignment of 16 species.
- Publication of two book chapters, one describing the classification of the red algae, the second a treatise on the biogeography of Australian seaweeds.
- 2383 new specimens of marine benthic algae have been added 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 in 2017-18 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.
- Prepare a revision of the book *Marine Plants of Australia*, to be published by The University of Western Australia Publishing.
- Finalise a paper describing a new species of the brown alga *Rosenvingea*, collected in early 2016 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 'WA 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

- 300 species have been prepared for uploading to *Florabase*.
- Numerous additional *in situ* and microscopic images of marine algae have been taken. Over 100 new images have been uploaded to ImageBank/*FloraBase*.
- Data for c. 2400 specimens newly added to the 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

- Continue preparation and finalize 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, KA Shepherd, M Hislop, T Macfarlane, B Rye, R Butcher, S Dillon, A Perkins, R Davis

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 1283 putatively new and undescribed taxa currently recorded in Western Australia, 577 of which are poorly known, geographically restricted and/or under threat (i.e. Threatened or Priority Flora). The lack of detailed information on these taxa makes accurate identification problematic and inevitably delays the Department's ability to survey and accurately assess their conservation status.

Aims

Resolve the taxonomy and expedite the description of manuscript or phrase-named plant taxa, particularly Threatened and Priority Flora and those taxa vulnerable to future mining activities.

Progress

- The taxonomic status of 19 conservation-listed, undescribed taxa endemic to Western Australia was resolved, enabling their formal description. The new taxa belong to a diverse range of genera (*Allocasuarina*, *Anticoryne*, *Chamaescilla*, *Dysphania*, *Eremophila*, *Hibiscus*, *Hydrocotyle*, *Leucopogon*, *Nymphoides*,*Rinzia*, *Styphelia* and *Tetratheca*) and are ranked as Threatened (1 sp.), Priority One (9 spp.), Priority Two (2 sp.) or Priority Three (7 spp.) under departmental conservation codes.
- Two Threatened species, *Asterolasia nivea* and *A.* sp. Kalgan River (S. Barrett 1522), were found to be taxonomically indistinct from *A. grandiflora* and *A. hyalina* respectively, resulting in their removal from Western Australia's vascular plant census and revised conservation assessments and recommendations. Three additional phrase-named taxa in *Ptilotus* and *Scholtzia* were also found to be synonymous with known species.
- Threatened flora nominations for *Lasiopetalum* sp. Mount Caroline (S.D. Hopper SDH 6381) and *Stylidium asymmetricum* were prepared and submitted in collaboration with regional staff.
- Papers describing new, conservation-listed species of *Acacia*, *Brachyloma*, *Hysterobaeckea*, *Lasiopetalum*, *Lepilaena*, *Thysanotus* and *Wurmbea* were submitted for peer review or progressed.
- *Hakea* sp. Great Victoria Desert (L. Cockram LAC 139) and *Thryptomene*sp. Hyden (B.J. Lepschi & L.A. Craven 4477) were added to the state's vascular plant census and subsequently listed as Priority One under departmental conservation codes.

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

- Analysis of the genetic diversity, mating system and reproductive biology of *Hakea oldfieldii* has been completed. A second paper has been published in *Ecology and Evolution*. The three population areas in Perth Hills, Busselton and south coast showed significant genetic divergence as expected but there was also significant population divergence within these areas indicating low historical connectivity. Low diversity is associated with historical processes rather than recent fragmentation. Populations were predominantly outcrossed even when severely reduced in size, indicating little effect of inbreeding in small populations, but reproductive parameters were higher in small populations with intact vegetation compared to disturbed sites, highlighting effects of understorey on pollinator abundance and behaviour.
- Analysis of reproductive output, mating system variation, progeny fitness and genetic diversity in relation to habitat fragmentation has been completed for *Eucalyptus wandoo*. A paper is in final preparation. 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.
- Papers on pollen dispersal, mating systems, reproductive biology and demography in *Banksia nivea* ssp. *uliginosa* have been prepared.

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.
- The *H. oldfieldii* study showed that conserving populations in intact habitat is a high priority to maintain the genetic and ecological processes in naturally fragmented and insular species. Management interventions, such as enrichment planting to increase the diversity of pollen donors, should also include habitat and understorey restoration to facilitate effective mating patterns. Seed collection should prioritise populations with intact habitat to maximise genetic diversity.
- 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, pollen dispersal, mating systems, reproductive biology and demography in *B. nivea* ssp. *uliginosa*.
- Publish paper on reproductive output, mating system variation, progeny fitness and genetic diversity in *E. wandoo*.

Translocation of critically endangered plants

SP 2001-004

L Monks, R Dillon, D Coates

Context

The contribution of translocations (augmentation, re-introductions, 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 two Critically Endangered plant species at two sites.
- Monitoring was undertaken for 44 sites of 31 taxa translocated in previous years.
- Detailed demographic monitoring was undertaken for *Acacia cochlocarpa* subsp. *cochlocarpa* at translocation and natural sites, and demographic monitoring will be used to develop a Population Viability Analysis (PVA) model for this subspecies.
- Drafting of a publication on flora translocation methods and success criteria is nearing completion.

- Paper on experimental approaches to improving establishment success and persistence of threatened plant translocations has been accepted for publication in *Ecological Management and Restoration*
- Assisted District and Regional staff plan and implement a range of flora translocations. Planning commenced for translocations of *Banksia brownii, Lambertia orbifolia, Schoenia filifolia* subsp. *subulifolia*, and *A. cochlocarpa* subsp. *cochlocarpa.*

Management implications

- Translocations lead to the improved conservation status 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 Parks and Wildlife 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 *Lambertia orbifolia* PVA study.
- Continue data collection for development of a PVA model for translocated and natural populations of *A. cochlocarpa* subsp. *cochlocarpa*.

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

- Seed has been extracted from collections from two translocated *Banksia brownii* populations and seven natural populations to assess mating system variation and benchmark mating system performance in the translocated population.
- Seed collections are underway for natural and translocated populations of *Lambertia orbifolia* to assess mating system variation and genetic variation, and benchmark mating system performance and genetic diversity in translocated populations.
- Data on mating system variation in two sister triggerplant species (*Stylidium affine* and S. *maritimum*) with contrasting breeding systems is currently undergoing re-analysis.

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

- Complete data analysis and draft paper on the mating system in *Stylidiumaffine* and *S. maritimum*.
- Commence 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 has been used to develop climatic layers at appropriate scales for modelling the distribution of short range endemics under the influence of a projected warmer and drier climate.
- Submitted a paper on fire response of Threatened Flora to a scientific journal.

- Undertook analysis of range size in Threatened and Priority shrub species in the south-west to better understand possible extinction debt.
- Began demographic studies of Threatened Flora on the south coast to investigate the impacts of fire and disease.

Management implications

- A 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.
- The analysis of extinction debt in the highly fragmented south-west landscape will further assist in the development of protocols for prioritising Threatened Flora for management intervention and recovery actions.
- Micro-climatic surfaces for the Ravensthorpe Range and surrounds will assist with vulnerability and adaptation 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

- Continue monitoring *V. staminosa* subsp. *staminosa* and begin analysis of long term monitoring data-set investigating the effects of declining rainfall on the recent dynamics of the population.
- Publish paper on the climate surfaces developed from the micro-climate sensor array in the Ravensthorpe Range.
- Publish paper on fire responses of threatened flora.
- Continue analysis of Threatened and Priority Flora database records to estimate the level of extinction debt for threatened plants in the highly fragmented south-west landscape and prepare a draft manuscript.
- 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 Cochrane, 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 145 seed collections (81 species) were banked at the Threatened Flora Seed Centre during 2016–17; 81 of these collections were listed as Critically Endangered, Endangered or Vulnerable (Threatened Flora).
- Duplicates of 42 collections were sent to the Millennium Seed Bank Kew as a risk management strategy.
- 46 germination tests were conducted.
- Seedlings of five Critically Endangered species were provided for translocation.
- The seed bank now contains 5894 collections (1890 taxa) representing 334 Threatened Flora, 708 Priority Flora and 848 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 restoration of *Banksia* woodland.
- 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, B Macdonald, M Hankinson

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 relationships among the disjunct populations of *Eucalyptus virginea* and related species.

Progress

- Analysis of genomic data in the *C. quadrifidus* species complex is in progress to support taxonomic determinations, and the importance of phylogenetic history versus current climatic conditions on morphological variation is being assessed.
- Genotyping of 10 populations of *B. biterax* from Busselton and the Albany region using genomics and cpDNA sequences has been completed and analysis is being undertaken.

- Sequencing of 14 populations of *B. densa* with cpDNA gene regions has been completed and analysis is being undertaken.
- Collections of leaf samples from *E. virginea*, *E. relicta*, *E. lane-poolei* and *E. decipiens* have been made and DNA extraction has been undertaken.

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 of *B. biterax* confirms they should be managed as separate lineages. Augmentation of the small Busselton populations needs to use seed collected form these populations.
- Phylogenetic relationships among populations of *B. densa* will assist in determining taxonomic status of the morphologically different population.
- Phylogenetic analysis of relationships among disjunct populations of *E. virginea* will inform management of the populations.

Future directions

- Analysis of genomic data in *C. quadrifidus* and associations with environmental variables will be completed.
- Analysis of *B. biterax*, *B. densa,* and *E. virginea* will be completed.

Ecosystem Science

Program Leader: Lachie McCaw Applied research undertaken by the Ecosystem Science Program seeks to understand the factors and processes that determine the overall health and productivity of lands managed by the Department of Parks and Wildlife, which include state forests, national parks and other conservation reserves. This research is aligned to the information needs of Parks and Wildlife and the Forests Products Commission. Strong collaborative linkages exist with universities, cooperative research centres, CSIRO, the Bureau of Meteorology, other government and private sector research providers and the corporate sector.

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

SP 2017-022

M Byrne, R Mazanec

Context

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

- Genotyping-by-sequencing has been undertaken for 23 populations of marri from across the range, generating 10,000 SNP loci. Analysis showed low levels of genetic structure (F_{ST} = 0.05) with isolation by distance in a north-south orientation. After controlling for population structure, SNPs associated with temperature, rainfall and aridity were identified. For temperature, the allelic turnover occurs in the hotter region of the distribution, while the allelic turnover for rainfall occurs in the wettest or driest parts of the distribution. Annotation of adaptive variants suggests that some functional genes may play roles in the species' adaptation to differential environments.
- Provenance trials with 18 provenances and 170 families planted at Mt Barker and Margaret River have been measured for tree growth (height, basal diameter) and disease resistance (shoot blight), and analysis for variability and heritability of traits is underway. Growth and disease resistance both show moderate levels of genetic heritability (0.2 to 0.3). Heritability was greatest in warm and cool regions with admixture found in the intermediate region potentially increasing epistatic effects. There was 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 subset of trees in the trials has been assessed for stomatal conductance, leaf transpiration and net photosynthesis to estimate the susceptibility to cavitation and drought. Data analysis of provenance variation for these traits has commenced.
- 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. Data analysis has commenced and initial 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 southwest 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

- Genomic data analyses will be completed and paper written.
- Analysis of provenance trial data for growth, disease and ecophysiological traits will be completed and papers written.
- Analysis of glasshouse experiment will be completed and paper written.

Development of an environmental risk strategy for sustainable agricultural planning in the Kimberley

SP 2015-009

C Munday, M Byrne

Context

The anticipated increase in export beef markets from the Western Australian rangelands, including the Kimberley and Pilbara, must be supported by an increase in production. Expansion of mosaic agriculture around irrigation precincts and improved rainfed forage can potentially broaden the feed base of rangeland grazing systems. This project forms part of the Department of Agriculture and Food Western Australia (DAFWA) strategic planning for sustainable mosaic agriculture in Western Australian project. This project will investigating the introduction of pasture species to improve the productivity and profitability of rangeland pastoral systems. Many of these species are not native and may have the potential to become environmental weeds resulting in a loss of biodiversity from natural environments. Weed risk assessment (WRA) provides transparent, scientifically based, information to help in species selection and management to minimise the risk to natural assets.

Aims

The project will modify the Future Farm Industries CRC WRA system and supporting environmental risk framework, developed in a previous Parks and Wildlife project, to provide information about the selection and management of species to minimise environmental weed risk. WRAs will be completed for a range of species considered to have agricultural potential in irrigated mosaic or dryland pastoral agricultural systems. A technical committee of weed and agricultural experts will provide advice.

Progress

- The Invasiveness and Impact sections of WRAs have been completed for 15 non-indigenous species with possible potential in pastoral systems, supported by documentation outlining the environmental risk strategy.

Management implications

- The drive to increase productivity of pastoral systems in the rangelands of Western Australia has increased the demand to find pastoral species that will increase the seasonal availability and nutritional value for feed lot and grazing systems. However many of the characteristics that make a species suitable as a pasture plant may also make it an environmental weed with potential to damage the natural environment and high costs implications for control or eradication. The WRA and a supporting environmental risk strategy developed in this project will inform species selection to balance potential productivity increases with the cost to natural assets. Where appropriate the information will also inform the development of management plans to minimise risk to the environment.

Future directions

This project has been completed.

Understanding the changing fire environment of south-west Western Australia

SP 2014-001

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

- Soil Dryness Index data for Manjimup and Dwellingup were used to calculate the cumulative moisture deficit during each fire season from 1992 to 2016 based on threshold values of 50, 140 and 165 mm. A number of years showed a strong dry anomaly during the fire season, which was not coupled to below-normal rainfall during the winter months. Four of the five driest seasons were common to both Manjimup and Dwellingup, indicating a relatively high level of spatial coherence in the severity of summer dryness across the south-west forests.
- Fire behaviour data from the Waroona bushfire of early January 2016 have been made available to the Bushfire and Natural Hazards Cooperative Research Centre for a project on coupled fire-atmosphere modelling. A manuscript examining meteorological drivers of extreme fire behaviour during this event was prepared and submitted for publication.
- The reconstruction of fire spread of the Waroona bushfire was made available as one of ten case studies used to evaluate the performance of bushfire simulators in a project coordinated by the NSW Rural Fire Service and Bureau of Meteorology.
- Forty years of lightning ignition data from the Warren region were collated and verified for a collaborative project on lightning climatology involving the Bureau of Meteorology, CSIRO and the Department.
- 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, and where possible linked to existing Forestcheck monitoring.

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 re-focus 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

- Finalise publication of the manuscript on meteorological drivers of extreme fire behaviour during the 2016 Waroona bushfire.
- Finalise and submit a manuscript analysing temporal and spatial patterns of lightning ignition for the Warren region, and continue to investigate climatic factors associated with lightning ignition.
- 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.
- Continue to monitor and report on the outcomes of the adaptive management trial of prescribed burning in regrowth forest.

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 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

- Analysis of association between allele frequencies and ecological variables has been completed.
- A manuscript detailing the patterns of genetic structure and landscape variables that explain the genetic differentiation across the catchment for *Astartea leptophylla* and *Callistachys lanceolata* has been completed and submitted.
- 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 prepared and is undergoing revision.
- 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

- Complete any required revisions for *A. leptophylla* and *C. lanceolata* genetic patterns manuscript.
- Finalise revision of manuscript on signals of adaptation for *A. leptophylla* and *C. lanceolata* and submit.
- Complete manuscript on *T. linearifolia*genetic structure and signals of adaptation.

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. This work is part of the Kingston Project and a complement to the FORESTCHECK monitoring program.

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 autumn 2017.
- Ngwayir (western ringtail possum) populations in the greater Kingston area remain extremely low having declined to almost undetectable levels between 2001 and 2013. Spotlight detections increased slightly in 2014 and this trend has been sustained, but detections remain at less than 5% of the level typical of the pre-2000 era.
- Data from this study has been published in two papers in *Journal of Mammalogy and Wildlife Research,* describing the population trends and declines of multiple native species in the Upper Warren region.

Management implications

- Information on the impacts of timber harvesting on terrestrial vertebrates will lead to improved ecologically sustainable forest management practices and the conservation of biodiversity.
- The decline of multiple species of native mammals in the Upper Warren area is of serious concern requiring action, especially given the high conservation value of the area and the importance of the populations found within the area. Understanding the factors responsible for these population changes provides critical context for informing management of fauna in areas subject to timber harvesting and other management activities.

Future directions

- Responses to timber harvesting of terrestrial vertebrates will be analysed and prepared for publication.

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 h^{-1}. 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

- Fire behaviour data have been collected from three sites (Albany, Frankland and Moora Districts) and data analysis has commenced.
- Collaboration with Blackwood District has developed an adaptive management framework for a planned burn at Boranup that includes coastal heath and mixed shrubland. Experimental sites were established in a planned burn at Boranup.
- Fire behaviour during the November 2015 Two Peoples Bay bushfire has been documented and is currently being used to validate existing fire rate of spread models. Findings were presented to South Coast Region.
- Regular sampling was conducted at Yanchep throughout the year for a study evaluating the potential application of remote sensing to determine live fuel moisture content in shrublands.
- A fire behaviour prediction system for semi-arid heath and mallee-heath was presented in the form of a simple guide suitable for use in the field by practitioners.

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

- Collect fire behaviour metrics from planned burns as these are implemented to verify the performance of the collaboratively-developed fire spread model for Western Australian shrublands.

- Plan and conduct further experimental burning to quantify threshold conditions for sustained fire spread in shrublands of different structure and time since fire.
- Finalise and publish the reconstruction of the Two Peoples Bay bushfire.
- Analyse and publish the findings from the study of remote sensing of live fuel moisture content.
- Expand the scope of the project to include quantification of fire severity and patchiness at the operational burning scale.

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

- Fire treatments are now complete and analysis of this very large database has commenced.
- Patterns of plant community response to various fire regimes have been identified.

Management implications

- Further data analysis is required to assess the long term effects of fire on floristic composition and richness, and implications for management. Being one of a few long-term studies of its kind around the world, the findings of this research 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

- Prepare, analyse and report on data collected since 1986, and prepare a scientific paper for publication.
- Implement technology transfer program through formal and informal presentations and publications.

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.

Progress

- Fauna and vegetation were surveyed at 70 sites in the north Kimberley in the 2016 dry season. A further 42 sites were surveyed for vegetation only.
- Mammal distribution patterns are strongly influenced by vegetation cover, cattle impacts and fire regime. Mammals abundance is negatively related to the extent of surrounding country burnt and frequency of late dry season fire, and positively to ground layer vegetation cover.
- Mammal species and groups have increased with active fire management from 2011, demonstrating positive benefits for threatened mammals from patchy burning in the early dry season.
- Surveys at Mirima National Park in the East Kimberley have revealed recent declines of some mammals. This has occurred following cane toad invasion, loss of apex reptilian predators (large goannas and elapid snakes) and increases among meso-predatory snakes including olive pythons and tree snakes. This suggests a cascading impact on communities following cane toad invasion based on changes to predator interactions and dietary preferences.

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 (*Conilurus penicillatus*). 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 declines in the North Kimberley.

Future directions

- Monitoring and evaluation will continue to demonstrate ongoing management effectiveness of the Landscape Conservation Initiative.
- Evaluation of factors influencing mammal abundance and richness between years will be undertaken using a statistical modelling approach.
- Pursue studies into cascading impacts of cane toad on mammals and savanna ecosystems to better understand the complexities of these interactions.

Climate-resilient vegetation of multi-use landscapes: exploiting genetic variability in widespread species

SP 2012-002

M Byrne, B Macdonald, R Binks

Context

Multi-million dollar investments in the restoration of Australia's degraded and fragmented multi-use landscapes currently take little account of climate change. Until recently there has been a strong focus on maintaining local genetic patterns for optimal restoration. In a changing climate this paradigm may no longer be relevant and a new framework is urgently needed. The proposed project will deliver such a framework by undertaking pioneering research and development at the interface between molecular genetics, plant physiology and climate adaptation. Specifically, it will test hypotheses of adaptation in widespread eucalypt species, by investigating correlations between key physiological traits and genetic signatures of adaptation across climatic gradients utilising recent advances in eucalypt genomics. Addressing this question will ensure optimal, climate-resilient outcomes for Australia-wide investment in ecological restoration, offering a novel solution to ecosystem adaptation in changing environments.

Aims

The project will test the following alternative hypotheses:

- Widespread species, having evolved under highly variable environments, retain high potential for adaptability to environmental change within the gene pool of local populations or individuals (implying that genetic material sourced from local populations will have tolerance to changing climatic conditions).
- Widespread species, having evolved across wide ecological gradients, comprise a suite of locally adapted sub-populations (implying that genetic material should be sourced not from local populations but from distant and potentially resilient populations that are pre-adapted to the future climate).

Progress

- Analysis of genomic variation and environmental traits in *Eucalyptus loxophleba* showed evidence of adaptation to climate across an environmental gradient. A paper detailing this climate adaptation has been published in *Biological Journal of the Linnean Society*.
- A paper describing the genomic architecture of climate adaptation in three species, *E. salubris* and *E. loxophleba* from Western Australia and *E. tricarpa* from Victoria has been published in *Genome Biology and Evolution*.
- 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.

Management implications

- The findings of both genetic adaption to local conditions and capacity for plastic responses highlight the complex nature of climate adaptation. Widespread eucalypts are therefore likely to be able to adjust to a changing climate to some extent, but selection of seed sources to match projected climate changes may confer greater climate resilience in environmental plantings. A strategy of 'climate-adjusted provenancing' with seed sources biased toward the direction of predicted climatic change is recommended for restoration and revegetation.

Future directions

Publish paper confirming geographic distribution of two lineages in *E. salubris*.

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

- Re-measurement of tree diameter and bark thickness was completed in the long-term thinning experiment in 100 year old regrowth jarrah forest at Inglehope block near Dwellingup. Data from the experiment is being used to verify predictions from a process-based forest growth simulator.
- Initial planning commenced for a second thinning of the 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

- Collate tree growth data from the Inglehope experiment and make data available for verification of growth simulations by Forest Management Branch.
- Analyse and report on trends in tree and stand growth at Inglehope, with a focus on links between climate and growth.
- Plan for second thinning at Warren, with the intent of maintaining an experimental design compatible with long-term monitoring of 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 paper investigating climate effects on GLS outbreaks was published in *Austral Entomology*.
- A study investigating effects of understorey removal by fire on pheromone trap catch was initiated. Catch data have been summarized and analyzed. Dense understorey interferes with pheromone trap effectiveness, while fire enhances trap catch in forest with a dense understorey by removing the shrub layer. Testing for a vegetation effect using a dryness index as a proxy for vegetation density showed negligible impact on the historical data from long term GLS population monitoring sites. A draft manuscript has been prepared and will be submitted once additional data has been collected.
- A paper detailing the incursion of a psyllid, *Cardiaspina fiscella* has been published in the *Journal of the Royal Society of Western Australia*.

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.
- Pheromone trapping is effective in monitoring GLS populations and could be used routinely to identify the likelihood of GLS outbreak. Moth populations are a good predictor of subsequent larval populations and may provide early warning of outbreak events in the context of climate data.
- 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 eucalypt

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.
- Vegetation structure and species composition, and fire regimes affect the rate of spread and control options for potentially invasive and exotic moth species in jarrah forest which use pheromone based mate finding.
- The psyllid *C. fiscella* is currently in Western Australia on exotic eucalypts and has the potential to infest karri.

Future directions
- Continue pheromone trapping at long-term monitoring sites to validate models of population outbreak driven by climatic factors.
- Collect further data relating fire and vegetation density effects on the efficacy of GLS pherome trap catches.
- Investigate vegetation species composition and fire effects at different trap heights using the GLS pheromone system.

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

SP 2011-011

C Yates, M Byrne, S Tapper

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
- Analysis was completed for patterns of floristic composition in GO plant communities and their relationships with climate, topographic and microhabitat features on outcrops. A paper is in preparation.
- Ecological niche models for the threatened *Ornduffia calthifolia* and the rare *O. marchantii* revealed that under the influence of projected climate change, topography and micro-habitats in the Porongurups will provide refugia for both species, but limits to this capacity may be reached if global warming exceeds 2℃. A paper has been published in *Annals of Botany*.

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

- Complete analysis of the floristic dataset from 17 GOs and model the influence of climate, microclimate and soil depth on GO plant community composition.
- Write journal papers on ecological evidence for granite outcrops as historical and future climate change refugia.

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.
- Investigate pathways to weed invasion in the GWW.

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 pools.
- Data from the chronosequence have been used to: (i) develop a conceptual model of vegetation dynamics for the unique stand-replacement temperate eucalypt woodlands of southwestern Australia (manuscript in preparation); (ii) review the composition, biogeography, environmental correlates and ecology of Australia's temperate eucalypt woodlands (chapter in press for the book *Australian Vegetation*); and (iii) locate a second population of the critically endangered arid bronze azure butterfly, by using ant records.
- A revised model for estimating the time since fire of long-unburnt gimlet woodlands has been developed and presented at the 2016 Ecological Society of Australia conference.

- Tree and shrub, woody debris, litter, and soil carbon pools were measured at a subset of the gimlet chronosequence sites.
- Three Science and Conservation Division Information Sheets outlining the management implications of the research were published: (i) visual fuel assessments in gimlet woodlands; (ii) changes in ant communities across the gimlet chronosequence; and (iii) predictors of weed occurrence and delineation of priority weed species in the GWW.

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.
- 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.
- Contemporary invasive plant spread in the GWW could be reduced via: (i) targeting abandoned and current settlements for removal of disjunct weed populations; (ii) minimising new settlement creation in locations currently remote from towns; and (iii) closing water points on conservation estate to reduce disturbance-induced weed recruitment. Considering future climate tolerance in weed species prioritisation results in a feasibly small selection of taxa for pre-emptive regional-scale eradication or containment.
- GWW woodlands have little grass in comparison to other temperate woodlands. If perennial grass weeds (such as buffel grass) become widely established, potentially facilitated by climate change, substantial fire regime shifts and subsequent extensive loss of mature woodlands are plausible.
- Knowledge generated through this project has been incorporated into eucalypt woodland fire ecology training being delivered to Department of Parks and Wildlife staff.

Future directions

- Finalise journal publications concerning vegetation dynamics model for stand-replacement temperate eucalypt woodlands and the refined model for estimating time since fire of long-unburnt gimlet woodlands.
- Analyse measurements of carbon pools across the gimlet chronosequence to determine the role of fire management in carbon sequestration.
- In collaboration with Birdlife Australia, complete analyses and publications on changes in bird communities with time since fire across the gimlet chronosequence

Identification of seed collection zones for rehabilitation

SP 2006-008

M Byrne, D Coates, S Mcarthur

Context

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

Aims

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

Progress

- Analysis of microsatellite variation and cpDNA variation in *Allocasuarina humilis* showed patchily-distributed forest populations were substantially more differentiated with significantly lower within-population diversity than semi-continuous heath populations. Phylogeographic analysis revealed evidence for earlier colonization of heath than forest and recent expansion into wetter forests, consistent with progressive long-term climatic drying. A paper has been published in *Journal of Biogeography*.
- Analysis of microsatellite variation and cpDNA variation in 28 eight 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.
- Analysis of nuclear genetic variation and cpDNA variation in marri (*Corymbia calophylla*) showed little genetic structure 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 has been submitted for publication.

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. Current data on *Kenedia coccinea, Bossiaea ornata* and *A. 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

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 the preparation of scientific papers reporting the second round of monitoring completed between 2007 and 2012. A manuscript that synthesises 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 finalised.
- Seven monitoring grids in Wellington District burnt by the large Lower Hotham bushfire in February 2015 were re-sampled. Invertebrate pitfall and light trap sampling was undertaken on burnt sites in spring 2016 and autumn 2017. Monthly inspections to identify vascular plant species in flower have revealed a number of species not recorded previously at these grids, including a significant range extension and a potential new species.
- Two additional grids were established in Perth Hills District to expand the fire chronosequence to include examples of forest burned very recently. Sampling of stand structure, coarse woody debris, vascular plants, invertebrates and vertebrates was undertaken in autumn 2017.
- Analysis of factors affecting the consumption of coarse woody debris was undertaken using data gathered from 20 monitoring grids burnt by prescribed fire and bushfire. A manuscript presenting models for woody fuel consumption is being prepared.
- Trends in vegetation cover at each monitoring grid have been quantified using satellite imagery to provide a basis for reporting on forest condition for the Forest Management Plan mid-term performance report.

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 five 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 publication of 10-year 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.
- Utilise data from Forestcheck monitoring to inform the Forest Management Plan mid-term performance report.

Burning for biodiversity: Walpole fine-grain mosaic burning trial

SP 2004-004

N Burrows, J Farr, G Liddelow, B Ward, V Tunsell, A Wills, Frankland District Staff

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

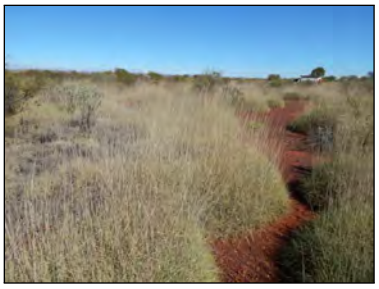
- Field work has been completed for this project. Data are being compiled, fungi and invertebrate collections have been sorted and documented. Data for invertebrates has been compiled and analysis has commenced.
- Draft papers on the effects of mosaic burning on crytpogams have been prepared.
- A collaboration with a US-based FRAGSTAT statistician has been very helpful in analysing landscape-scale mosaics.
- 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 successful workshop was held with fire ecologists from the University of Melbourne to share ideas and explore opportunities for collaborations.

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.



Project Rangelands Restoration: developing sustainable management systems for the conservation of biodiversity at the landscape scale in rangelands of the Murchison and Gascoyne bioregions–managing fire and introduced predators

SP 2003-004

N Burrows, G Liddelow

Context

Despite the relatively pristine nature of most of the arid interior (desert bioregions) and rangelands (beyond the pastoral zone), there has been an alarming and recent loss of mammal fauna, with about 90% of medium-size

mammals and 33% of all mammals either becoming extinct or suffering massive range contractions. There is also evidence of degradation of some floristic communities due to altered fires regimes. The extent and nature of change in other components of the biodiversity, including extant mammals, birds, reptiles and invertebrates is unknown. The most likely causes of the decline and degradation in biodiversity are introduced predators, especially the fox (*Vulpes vulpes*) and the feral cat (*Felis catus*), and altered fire regimes since the departure from traditional Aboriginal burning practices over much of the region. Taking an adaptive experimental management approach in partnership with Goldfields Region, this project aims to reconstruct some assemblages of the original native mammal fauna on Matuwa (Lorna Glen), a pastoral lease acquired by the Department. This will be achieved by an integrated approach to controlling introduced predators and herbivores, ecologically appropriate fire management, and fauna translocations.

Aims

- Develop efficient, effective and safe introduced predator (fox and feral cat) control technologies for the interior rangelands and the arid region.
- Reconstruct the original suite of native mammal fauna through translocation once sustainable feral cat control can be demonstrated.
- Implement a patch-burn strategy to create a fine-grained, fire-induced habitat mosaic to protect biodiversity and other values.
- Describe and predict pyric (post-fire) plant succession and describe the life histories of key plant species.
- Monitor the long-term trends in species assemblages and abundance of small mammals and reptiles in an area where introduced predators are not controlled compared with an area where they are controlled.
- Model the relationship between seasons (rainfall) and the frequency and size of wildfires.

Progress

- Aerial feral cat baiting was carried out on Matuwa (Lorna Glen) in July 2016 as part of the Western Shield and Rangelands Restoration programs. A network of 50 trail cameras was used to measure the effectiveness of baiting. The post-bait cat camera activity index (CAI) was 2.1, representing a 38% reduction in cat activity attributable to baiting. While this is a low level of knockdown, weather conditions were sub-optimal and the cat density prior to baiting was low. Expecting high levels of knockdown of an already reduced cat population is unrealistic – as the cat density decreases, baiting will be less effective unless significantly greater control effort is expended. The current cat density is about as low as we can expect to achieve with annual aerial baiting. In order to establish free ranging predator-sensitive species such as boodies, feral cats will have to be eliminated for a period of time while founder populations establish.
- The Matuwa fire management plan continued to be implemented, including further installation of fuel-reduced buffers around some fire management cells and core ignition. Some small patch-burning was carried out inside the predator-proof compound for wildfire mitigation and to create habitat diversity.

Management implications

- This project is providing insurance populations of threatened arid zone mammals.
- Information will inform guidelines for the proactive management of fire in the arid zone rangelands to reduce the severity (scale and intensity) of wildfires and to provide habitat choice through mosaic burning.
- Guidelines for controlling introduced predators in the arid zone rangelands will reduce this threat to native fauna. Reintroduction and protection of mammals of the arid zone rangelands, other extant fauna, vegetation and other elements of the biota will provide reconstruction of animal and plant assemblages in an arid zone ecosystem.
- A framework and protocol for assessing and reporting trends in ecosystem condition in arid zone rangelands will provide a basis for ecosystem condition monitoring.
- Future monitoring of cat density and baiting effectiveness on feral cats can be achieved through the use of cameras alone, delivering a significant cost saving for management.

Future directions

- Given that aerial baiting has been unable to further reduce the feral cat population, ground baiting will be trialled in conjunction with aerial baiting.

- Install trail cameras on Karara Karara (Earaheedy) (unbaited), to compare feral cat densities with Matuwa (baited).
- Assess and report on the effectiveness of feral cat and dog baiting to be undertaken in July 2017.
- Continue to implement the fire management plan including buffer burning and patch-burning. Carry out further patch-burning in the predator-proof compound.

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 (900-1100 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.

Progress

- Monitoring of groundwater levels, streamflow, stream salinity and stream turbidity continued in Yarragil 4X and 6C (treated), and Wuraming (control) catchments.
- Monitoring of groundwater levels, streamflow, and stream salinity continued in Yarragil 4L, which was thinned in the mid-1980s, to examine the effect of thinning on stream water quality and quantity.
- A paper reviewing the long-term hydrological response to thinning in Yarragil 4L was submitted for publication in the *Journal of Hydrology*.
- Groundwater bores were located and re-measured in 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

- These 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 to KPI 10 for the *Forest Management Plan 2014-23* which relates to stream condition and groundwater level within fully forested catchments.
- Monitoring in these catchments helps inform the effects of silviculture practices on water production.

Future directions

- Continue monitoring of groundwater levels, streamflow, stream salinity and turbidity and rainfall.
- Re-measure forest density along fixed transects in Yarragil 4X and 6C to determine the forest regeneration response to the timber harvest and silvicultural treatments.
- Re-measure tree growth in Yarragil 4L to determine the long-term response to thinning, and prepare a manuscript for publication.
- Progress planning for a second thinning in Yarragil 4L, 35 years after the previous thinning, to inform silviculture practices on water production.

- Review the network of existing groundwater bores in experimental catchments in the Warren Region to identify those bores which should be monitored to inform the mid-term performance report on KPI 10 of the *Forest Management Plan 2014-23*.

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

SP 1998-007

M Byrne, D Coates, S van Leeuwen, R Binks, E Levy, M Millar, S Mcarthur, B Macdonald

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

- A paper on genetic patterns in *Acacia ancistrocarpa* and *A. atkinsiana* has been published in *PLoS One*. *Acacia ancistrocarpa* has moderate haplotype diversity with most populations showing specific haplotypes. Nuclear diversity was moderate with little genetic structure across the Pilbara populations of this widespread species. In contrast, the Pilbara endemic, *A. atkinsiana* had low haplotype diversity with little geographic structure. Nuclear diversity was low and genetic differentiation among populations was moderate.
- A paper on genetic patterns in *Eucalyptus leucophloia* has been accepted for publication in *Journal of Biogeography*. This species shows genetic signature of the Hamersley and Chichester Ranges being a historical refugium, supporting a previous hypothesis of inland ranges being refugia in the Australian arid zone.
- A paper on the genetic diversity and differentiation in the rare *Aluta quadrata* has been published in *Australian Journal of Botany*. The species shows high nuclear genetic differentiation but no chloroplast haplotype variability indicating that the geographic separation of the three population locations is leading to contemporary genetic differentiation but is not a result of historical isolation.
- Studies are nearly complete for another eight species in the Pilbara for the identification of seed collection zones. Collections and microsatellite genotyping have been completed for all eight species, *Petalostylis labicheoides*, *Indigofera monophylla*, *Senna glutinosa*, *Corymbia hamersleyana*, *A. pruinocarpa*, *A. hilliana*, *A. spondylophylla* and *Mirbelia viminalis*. Reports have been written to summarise the results and provide provenancing recommendations for all species. Chloroplast analysis is currently being finalised.
- A paper on phylogeographic pattern and genetic diversity in *Mirbelia* sp. *bursarioides* and *Grevillea globosa* has been published in *Biological Journal of the Linnaean Society*.
- A synthesis paper on modelling seed collection and restoration establishment scenarios for *G. paradoxa*, *Melaleuca nematophylla, Mirbelia* sp. *bursarioides* and *G. globosa* is being prepared.

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

- Analysis of the current eight Pilbara species will be completed and recommendations on seed collection zones will be made.
- Genetic diversity and phylogeographic patterns will be investigated in two more Pilbara species.

Wetlands Conservation

Program Leader: Adrian Pinder The Wetlands Conservation Program undertakes research in a range of disciplines to support the management of wetlands in the State's conservation estate. Key areas of research are biological survey, ecological monitoring, wetland ecology and hydrology. Surveys of aquatic flora and fauna, at scales ranging from individual wetlands to regions, provide knowledge of patterns in the distribution of aquatic biodiversity required for conservation reserve design, assessment of species and communities conservation status and prioritisation of on-ground management. Targeted physical and biological monitoring programs, provide managers with information on effectiveness of management in protecting wetlands and rivers (e.g. management of the south-west forests) and effects of threatening processes, especially altered hydrology and water quality (such as that resulting from drainage, land-use changes, climate change and water resource development). Research into key hydrological processes are critical for designing effective management and mitigation strategies.

Hydrological function of critical ecosystems

SP 2016-005

J Rutherford, L Bourke

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 selected where dominant processes driving their behaviour are complex, but not unique, with results feeding back into coarser scale frameworks to reduce uncertainty and predict areas where ecosystems have a similar hydrological function and response to change. 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

- Determine ecohydrological management zones for Walyarta mound springs that have a similar hydrological function based on the sensitivity to changes in aquifer discharge (rate, volume and water quality).
- Develop strategies to manage Swan Coastal Plain claypans based on changes in hydrology induced by reductions in average winter rainfall, vegetation cover and anthropogenic controls.
- Review 1987 predictions of deleterious groundwater - estuary interactions and nutrient fluxes to estuary sea grass in Swan Estuary Marine Park at Lucky Bay and assess the broader scales risks.

Progress

- A two year hydrogeochemical, hydrogeophysical and numerical modelling investigation has confirmed that the majority of Walyarta springs are sustained by 'older' groundwater that moves to the surface through fracture systems.
- Eil Eil spring has been instrumented with hydrological monitoring equipment to understand the role of hydrology in maintaining the invertebrate communites.
- Hydrological information from satellite imagery has been used to develop a map showing the frequency of inundation of Lake Walyarta and to select surface water monitoring locations.
- Natural and anthropogenically altered surface water flows have been mapped and assessed at Brixton Street Wetland.
- Recommendations for closure and maintenance of tracks have been made.
- A study of groundwater and surface water interactions was undertaken and included the installation and monitoring of three bores and surface water levels within selected clay pans.
- A ground hydrogeophysics (electromagnetics) investigation mapped groundwater quality variation and transmissive zones in the aquifer that have potential to export nutrients to the Swan estuary.
- Groundwater sampling and analysis of Department of Water Bore IF14 show groundwater nitrate levels are elevated between 14 and 20m below ground level, where the geophysics indicated the aquifer is more transmissive.

Management implications

- A surface water monitoring program for the Walyarta (Mandora Marsh) mound spring TEC will allow regional staff to understand the hydrological dynamics of the system and track changes in water quality and quantity. This information will enable Parks and Wildlife to provide inter-agency advice on the need and extent of a groundwater protection zone for mound springs.
- Hydroecological information including the monitoring program will be transferable to other areas of the Kimberley Region and used to assist in the preservation of the TECs.
- Knowledge of hydrological function 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.
- An improved understanding of groundwater as a source of the nutrient fluxes into the Swan Estuary Marine Park will enable more informed spatial targeting of seagrass sampling and monitoring. It will provide an improved basis for developing robust hydrological monitoring programs on the Swan Estuary foreshore.

Future directions

- Complete the numerical modelling and assess monitoring requirements for mound springs identified as being the most sensitive to hydrological change.
- Download and interpret the hydrological data and information in surface water and groundwater data logger data from Eil Eil spring to understand the dynamics of spring moats and their connectivity with groundwater.
- Following 2017 winter rains, download and interpret hydrological data at the Brixton Street Wetland complex from loggers to increase understanding of claypan hydroperiods and their seasonal connectivity with shallow groundwater.
- Intergrate ground hydrogeophysics and groundwater hydrochemistry results for Swan Estuary Marine Park-Lucky Bay, report findings and recommend management strategies.

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 Muir-Byenup Ramsar wetlands.

This project has two components: 1) Re-surveys of aquatic invertebrates in Muir-Byenup Ramsar wetlands sampled in 1994 and 2004 and suites of wetlands further south sampled in 1993, addressing KPI3 of the 2014-23 Forest management Plan (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 faunas 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 Parks and Wildlife managed wetlands and their response and vulnerability to threats.

Progress

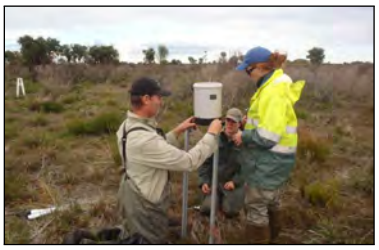
- Journal article was published in *Freshwater Biology* that assessed compositional turnover in aquatic invertebrates in south-west forest streams and representation of aquatic invertebrates in the conservation estate
- Article was published in *Wetlands Australia* on the Muir-Byenup Ramsar Wetlands.
- Conducted sampling of aquatic invertebrates in Tordit-Gurrup and Noobijup Swamp to monitor response to pH changes in the Muir-Byenup Ramsar wetlands.
- Carried out field work for monitoring of aquatic invertebrates in 20 forest streams.
- Identification, vouchering and consolidation of historical data for Muir-Byenup invertebrates is in progress.
- Collaborating with taxonomists to reconcile taxonomic issues between 1996/97, 2003/4 and 2014/15 data for the Muir-Byenup wetlands.

Management implications

- Re-surveying the Muir-Byenup Ramsar and other high value wetlands will provide the Department with knowledge of how these wetlands and their fauna have responded to threats over the last 20 years. This, in conjunction with results from the peat wetlands project (SPP2014-24), will assist the Department iwith making decisions about protecting remaining high conservation value wetlands versus taking remedial action at those where condition is declining.
- Forest Management Plan commitments will be addressed with respect to measuring change in condition of 1) currently healthy (reference condition) stream ecosystems (KPI1) and 2) Ramsar and nationally listed wetlands (KPI3). Results addressing these commitments will inform future forest management practices.
- The generalised dissimilarity modelling suggested that stream invertebrate communities in the south-west forests (at least the insect component in middle order reaches) are well represented in the conservation estate, but areas of the eastern jarrah forest have not been well surveyed.

Future directions

- Voucher Muir-Byenup invertebrates collected in 2014/2015, consolidate data from 1996/97, 2003/04, and 2014/15 and produce a report.
- Publish report with summaries of long-term trends (2005 to 2016) for all stream monitoring sites.
- Publish further papers examining impacts of declining rainfall and forest management practices on macroinvertebrate diversity in forest streams.
- 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

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 is delivering vital information on the long-term trends and variability in key determinants of wetland character and condition and, to a lesser extent, biological attributes.

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, and additional monitoring was undertaken following exceptional rains in February.
- Continuous water level and rain gauges were maintained on 10 southern wetlands with high conservation values. A report on such data from 14 wetlands was completed.
- The 1977-2015 SWWMP report was completed and key results communicated to managers.
- The final report on changes in waterbird usage and habitats of 11 mainly south coast wetlands, between the 1980s and 2008-2011, was completed.
- The ‘Salinity profiling of Lake Jasper in November 2015’ report was completed to provide a broader context for recent changes in salinity at the single monitoring point.
- Water level monitoring of the Vasse and Wonnerup estuaries and the Lower Vasse River Wetlands continued.
- Landsat shortwave infrared data was used to model depth to assist in filling gaps in the 40 year SWWMP depth records.

- Analyses of relationships between wetland character and aquatic fauna based on the Wheatbelt monitoring project largely completed.
- Following the first major fill event in more than 20 years, aquatic invertebrates and waterbirds were surveyed at Lake Toolibin.
- Data analysis for dominant overstorey trees commenced on Wheatbelt wetlands.
- Groundwater data collection was undertaken in autumn 2016.

Management implications

- Rainfall and water levels in south-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 provides early warnings of changes in three critical determinants of wetland ecological character (depth, salinity, pH) and helps inform where to focus management. The long-term nature of this project provides a unique context against which to assess the significance of contemporary observations and enables prediction of the effects of threatening processes and wetland management.
- SWWMP data provides vital information for planning and assessing management interventions, such as the hydrological interventions to reduce water levels in the Warden (Esperance) Ramsar wetlands, increase water levels at Jandabup and Thomsons Lakes and depths for water skiing at Lake Towerinning.
- Analyses of flora and fauna from representative wetlands will allow managers to predict future impacts of altered hydrology, assess management responses 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 rainfall predicts that longer-term shifts can be expected.

Future directions

- Complete write-up of the 15 years of fauna and flora monitoring at the intensively monitored wetlands and archive data.
- Re-focus the biological monitoring program to a smaller set of high conservation value south-west wetlands with current or imminent threats and clear management questions.
- By interpolation and modelling, fill gaps in the SWWMP water level time series to substantially increase the number of wetlands that can be included in decadal and multi-decadal trend analyses. Use this information plus an extra five years data to update the 1981-2010 analyses of region-wide trends in rainfall and wetland depths as a journal article.
- 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 futures of wetlands important for Australasian bittern and other fauna and flora under different climate scenarios.

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 (Toolibin Lake).
- Investigate the links between key ecological parameters (eg, tree and understory health, bird breeding, richness of aquatic invertebrates) and hydrological status (Toolibin Lake).
- Produce risk assessment framework(s) to prioritise conservation actions and assess the transferability of research outcomes.

Progress

- Developed an episodic rainfall monitoring program for Toolibin Lake and catchment to study the response and recession of groundwater and surface water to a short lived ~150mm rainfall event in February 2017.
- Used changes in regolith profile salt storage (resolved by comparing borehole geophysical logging measurements in 1997 and 2013) at Lake Toolibin to develop a conceptual salt balance model to determine where low salinity water (e.g. rainfall and low residence time surface water) recharged aquifers and higher salinity groundwater was moving laterally via throughflow.
- Incorporated a solute transport model into the Toolibin numerical groundwater model to test the conceptual salt balance and reduce uncertainty in the model water balance.
- Coupled an overland flow model to the Toolibin Lake numerical model to assess the performance of engineering infrastructure under different rainfall-runoff conditions.
- Produced reports recommending further rationalisation of groundwater and surface water monitoring programs for key wetlands assets in the Lake Bryde catchment.
- Developed a calibrated wetland-scale water balance model for Lake Bryde, simulating the period 1979 to 2017.

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 numerical 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.
- Complete a solute transport numerical model for Toolibin Lake to simulate changes in soil and aquifer water quality and examine results against quantitative conceptual models of changing soil condition and vegetation species resilience.
- Complete remaining five reports and prepare a Science Information Sheet.

Taxonomy, zoogeography and conservation status of aquatic invertebrates

SP 2014-025

A Pinder, K Quinlan

Context

The Wetlands Conservation Program undertakes research into 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 descriptions 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 (ex Lorna Glen) was submitted and is currently being revised.
- A book chapter on Australian and New Zealand aquatic oligochaetes is nearly complete.
- Genetic barcoding of selected invertebrates was undertaken for various projects.

Management implications

- The description of a new species of *Boeckella* copepod will allow consistent identification across the Goldfields region and therefore assist with environmental impact assessment.
- Biodiversity conservation planning advice is based on more comprehensive and consistent biodiversity analyses as a result of genetic barcoding of difficult to identify invertebrates.

Future directions

- Undertake similar taxonomic work 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 Ramsar 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 much 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

- Microbial assessment of two peat wetlands shows methanogenic bacteria responsible for the breakdown of organic material are absent below depths of 10cm in disturbed peat wetlands systems.
- Preliminary results on determining the role of different minerals and colloids to store and release metals and metalloids indicates their storage and mobility below the main peat horizon is dependent on the presence and cation exchange capacity of clay and iron oxide hydroxide minerals.
- Both lateral and vertical geochemical gradients driving acidification are resolved in the mineralogical and element mapping and correspond to the peat wetting and drying 'front' where discrete zones show sulphur stores transition from gypsum to pyrite.
- Peat substrate water retention under below average rainfall conditions is lower in peat wetlands that contain lenses of sand sized sediment.
- Higher than average winter rainfall in 2016 showed that peat wetlands affected by acidification did not recover the groundwater storage deficit, with surface water acidifcation persisting.

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 should be assessed so they can be actively managed.
- 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

- Undertake mineralogical assessment of acidity to incorporate into hydrogeochemical models to assess effects of wetting and drying under the current climate and make predictions under different conditions.
- Develop a three dimensional understanding of water, salt and acid stores in order to numerically model, spatial variability and identify wetlands where interventions are likely to be effective and the risk of peat fires reduced.
- 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.

Western Australian wetland fauna surveys

SP 2011-018

A Pinder, K Quinlan, R Coppen, L Lewis, F Thompson

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

- Completed a report on aquatic invertebrate diversity at springs of the Walyarta Ramsar site / Walyarta Conservation Park.
- Undertook the last round of field work for a Pilbara Corridors funded survey of flora and aquatic invertebrates of wetlands along the middle to upper Fortescue Valley in the Pilbara, completed identifications and produced a report.
- Worked with Goldfields Region to sample aquatic invertebrates in a number of additional wetlands with the aim of accumulating a regional dataset.
- Manuscript accepted for publication in *Freshwater Biology* on influence of dispersal ability and isolation of genetic diversification in Australia's arid zone.
- Completed identifications of wetland associated flora in the Cervantes to Coolimba region and progressed a paper on this work.
- Surveyed northern Wheatbelt wetlands for *Parartemia* brine shrimp to assist with determining the conservation status of *P. extracta*.
- Progressed identification of aquatic invertebrates from vegetated claypans of the south-west to analyse spatial patterns in these threatened but high value wetlands.

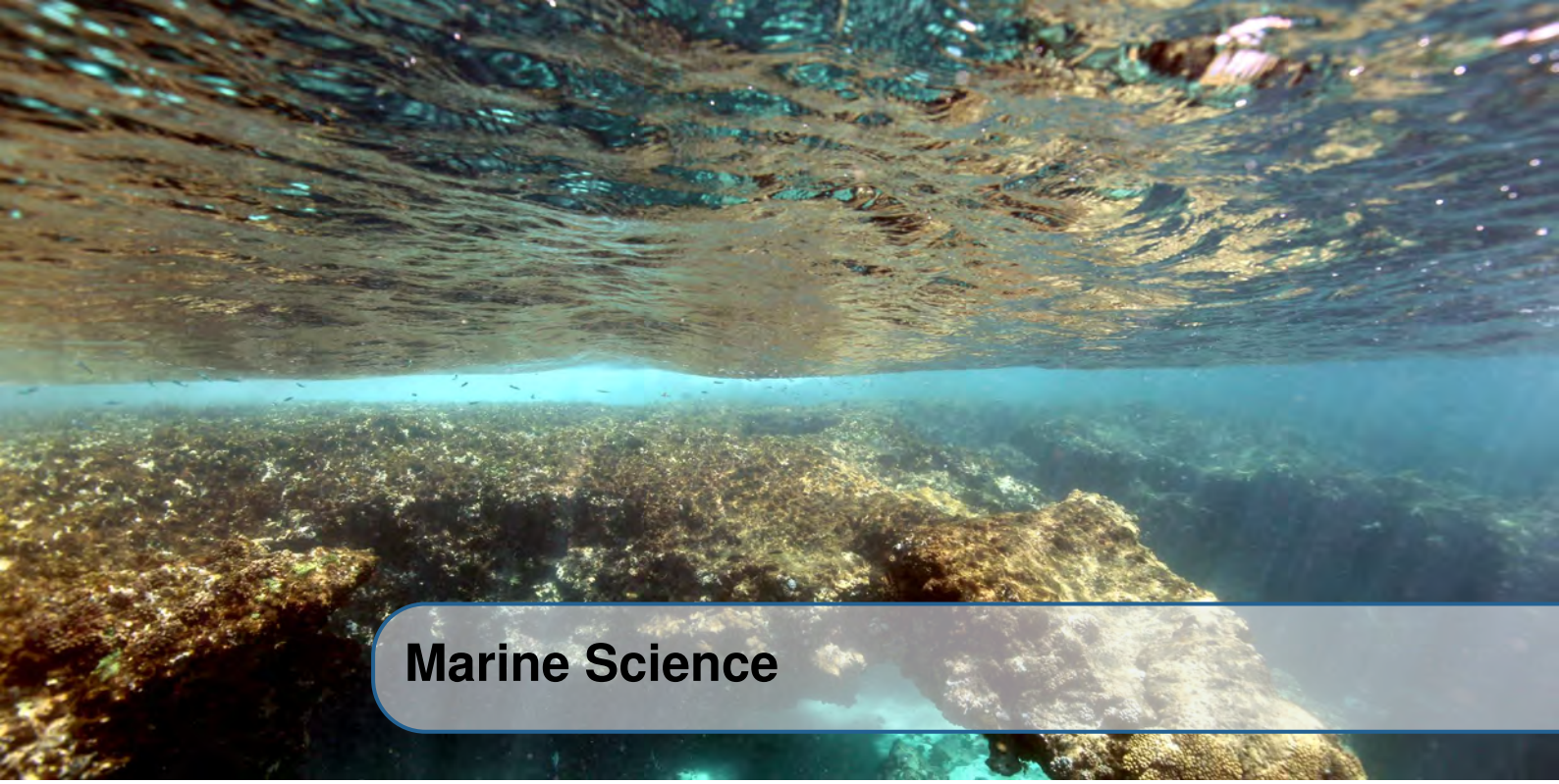
Management implications

- 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.
- Ongoing survey of aquatic invertebrates in Goldfields wetlands fills a gap in knowledge of biodiversity in an area still subject to intensive mining, thus allowing more informed assessment and approvals decision making.
- Survey work at Walyarta has contributed to assessing the relative condition and values of the springs and to the selection of sites for hydrological monitoring in response to abstraction of groundwater from the West Canning Basin. It will also be used to report on the ecological character of the springs when reporting on this Ramsar wetland to the Commonwealth. High turnover in species composition between 1999 and 2015 is likely to be natural, partly in responses to major episodic rainfall events, rather than a response to change in condition. This information was used to provide advice on monitoring invertebrates in the Interim Recovery Plan for the springs.
- In the Fortescue Valley, the survey of wetland biota will inform efficient 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.
- Vegetated claypans of south-western Australia support distinctive aquatic invertebrate and flora communities with high regional endemism and should be a priority for wetland management given their vulnerability to hydrological change.

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.

- Produce a poster and a Science Information Sheet on Fortescue Valley wetland survey.
- 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 during 2017/18.
- Participate in a biological survey of Kimberley region coastal mound springs.



Marine Science

Program Leader: Alan Kendrick The broad goal of the Marine Science Program is to ensure Parks and Wildlife'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 proposed Dampier Archipelago marine reserves

SP 2015-015

M Mohring, A Kendrick, T Holmes, S Wilson

Context

The Pluto LNG Project Offset D program includes the requirement to establish long-term monitoring reference sites in the proposed Dampier Archipelago Marine Park and Regnard Marine Management Area in accordance with the State Government's 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 to Parks and Wildlife's 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 proposed Dampier Archipelago Marine Park and Regnard Marine Management Area.

Progress

- Collaborative fieldwork was undertaken with Wheatstone/Pluto offset inshore cetacean researchers to establish seagrass and macroalgae monitoring sites.
- Trials of several seagrass and macroalgae monitoring methods were undertaken to inform the development of standard protocols for marine reserves in northern Western Australia.
- Mangrove monitoring sites were established in the study area and baseline data was collected from remote imagery analysis and in-situ field surveys.
- A second monitoring survey of coral and finfish communities was undertaken at sites established in 2015.
- A second *Landscope* article was published.

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 Parks and Wildlife 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 Dampier Archipelago Marine Park and Regnard Marine Management Area.

Future directions

- Second monitoring surveys of mangrove, seagrass and macroalgae communities will be completed.
- 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, R Douglas, C Douglass

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. All boat-based surveys have been completed and a paper on this work is now in peer review with the journal *Wildlife Research*.
- Two aerial surveys have been conducted in coastal waters from Exmouth Gulf to Port Hedland and extending offshore to the 20 metre depth contour (approximately 40km offshore) and including the Montebello Islands (approx. 60km from the mainland). Survey data is being used to produce estimates of dolphin 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.
- Survey data have been collated with environmental factors in MAXENT models of species distribution. These models are being refined with the importance of factors further explored to better understand how environmental factors contribute to dolphin distribution and high density hotspots.
- A 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 dolphin were collected and this will contribute to knowledge of the density and habitat use of these species in the Gulf.

Management implications

- This research will provide a baseline understanding of dolphin habitat use of 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 continue for a third year with a focus on the Dampier Archipelago area in partnership with the Pluto research and monitoring program.
- The third and final aerial survey will be conducted.
- Satelite tag design and deployment on humpback dolphins will be investigated to determine whether a pilot project can be conducted in the Pilbara to help inform the species' home range and movements.
- Species distribution models will be combined spatially with other data layers to assess risk to the target species (dugongs, humpback and bottlenose dolphins) across the Pilbara region.

Distribution and abundance estimate of Australian snubfin dolphins (*Orcaella heinsohni*) 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 WA and facilitate data-sharing between jurisdictions.

Progress

- A manuscript on cross-cultural knowledge of the distribution of snubfin dolphins in the Kimberley is being revised based on feedback from reviewers. This research has been accepted for presentation at the 2017 Biennial Conference on the Biology of Marine Mammals.
- 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.
- Additional data collected from Roebuck Bay in 2013 and 2014 has been added to the database.

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.
- Partnerships have been 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.

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.
- Utilisation of recent (2013 & 2014) data to investigate long-term site fidelity and home range of individual snubfin dolphins in Roebuck Bay.

Access and human use at Penguin Island and related implications for management of Marine Park assets and visitor risk

SP 2014-005

G Shedrawi, A Kendrick, M Rule

Context

Penguin Island is part of the Shoalwater Islands Marine Park and is the most northern significant breeding location for little penguins, *Eudyptula minor*, in Western Australia. The presence of migrating and resident seabirds and the unspoilt beaches makes Penguin Island an important seabird breeding colony and an attractive destination for residents and tourists, who generally access the island by ferry. A number of visitors choose to wade or swim to the island and Parks and Wildlife managers have identified this activity as a significant risk to visitor safety. Historically, such methods of crossing have resulted in near drownings that required Department staff to rescue people in the water and more recently, a drowning incident. Parks and Wildlife are continuing to implement a range of management strategies to mitigate this risk including recommendations from the Coroners working group. This project has been established at the request from Swan Coastal District to develop a better understanding of visitor crossings to Penguin Island by visitors, thus providing managers with relevant information for the design of mitigation strategies and actions.

Aims

- Determine social and environmental factors that characterise periods of high use of the sand bar crossing.
- Provide information to assist in the development and implementation of new and existing mitigation strategies that minimises visitor risk.
- Establish a system for recording beach arrivals of nesting little penguins, and high risk crossings by visitors to Penguin Island.

Progress

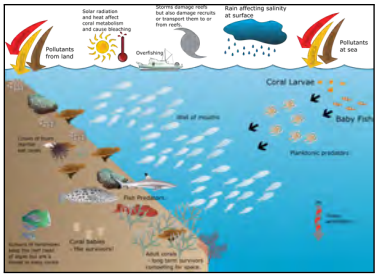
- Data concerning the number of people crossing the sandbar under different conditions collected between 2014-2015 have been analysed and have been compiled into an interim report for Swan region. The data showed that sandbar crossings were highest over summer and during weekends, school holidays and in calm weather conditions. Closures significantly lowered the number of visitors using the sandbar to access Penguin Island.
- The camera system for assessing the beach arrival of little penguins is in place and further work on monitoring little penguins in this way will form part of the Department's marine monitoring program.

Management implications

- The monitoring tool provides managers with information to assist the development of visitor risk mitigation strategies aimed at decreasing high risk crossings to Penguin Island. The preliminary information provided to managers indicates that management intervention strategies such as sandbar closures and signage may lower the proportion of visitors using the sandbar to access Penguin Island and indicates the relative value of patrols by Surf Life Saving Association life guards.
- Marine park managers now have an improved understanding of the numbers of little penguins landing on two major beaches during the breeding season that can be used to document long-term trends in abundance. This information is used to adapt on-ground management and to support reporting and community education.

Future directions

The final report will be delivered to Swan region and the project will be completed.



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

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 modeling 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 fourth year of the temporal study of recruitment processes.
- A fourth in-situ assessment of recruit corals on Onslow region reefs was undertaken using quadrats with underwater visual census and digital photographs.
- Post-dredging benthic images provided by Chevron were analysed to understand the size-class frequency distribution of corals in the Onslow region.
- Development of single-nucleotide polymorphisms (SNPs) for both coral species are still in progress with some delays caused by taxonomic and technical issues.
- Manuscripts are being prepared on analyses of mangrove, seagrass, coral and fish data.
- A manuscript on seascape genomics of reef fish submitted to the journal *Molecular Ecology* is in review.
- A paper on coral population genomics and connectivity was published in *Global Change Biology.*
- A review of dredging impacts on fishes was published in *Fish and Fisheries Review.*
- A *Landscope* article titled *Recruitment processes: A tale of survival* was published.

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

- Laboratory work will continue for the coral connectivity study, including SNP development for the corals, data analyses and manuscript preparation.
- 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 fourth year of data on coral settlement will be analysed and coral settlement tiles will be re-deployed 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

Dr M Depczynski (Australian Institute of Marine Science), Dr C Fulton (Australian National University), Dr B Radford (Australian Institute of Marine Science), S Wilson, T Holmes, M Rule

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 ~2000 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

- Fluctuations in the Southern Oscillation Index and strength of the Leeuwin current were found to be closely tied to annual abundance estimates of juvenile fish in macroalgal fields at Ningaloo. However, local juvenile fish abundance was more closely related to structural characteristics of macroalgae patches and there were species-specific habitat associations apparent. A paper describing these results has been accepted for publication in *Limnology and Oceanography.*
- Findings from the study were also presented to the public at the Whale Shark Festival at Exmouth and in newsletters for World Heritage Connect and the Australian Society of Fish Biology.

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.

Future directions

- Investigate how the influence of oceanic currents on juvenile fish abundance varies among taxa.
- Compile and analyse data 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 Parks and Wildlife 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 turtles Western Australia

Aims

- Determine the distribution and movement of sea turtlesand 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 connnectivity of turtles between habitats across their life stages (commonly between nesting beaches and foraging grounds).

Progress

- Flatback turtles were tracked from nesting beaches at Eighty Mile Beach, Montebello Islands, West Governor Island, Maret Islands and Thevenard Island and the results assisted in identifying inter-nesting habitat, migration routes and new foraging areas.
- Hawksbill and green turtles were tracked from nesting beaches at the Montebello Islands.
- Tracking fieldwork was undertaken in partnership with regional Parks and Wildlife 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

- The current studies have collected data that will enable calculations of time spent inside and outside marine reserves, the identification of high use migration corridors and the locations of important foraging areas and interesting habitats.
- This study has already identified new key habitats used by the Northwest Shelf flatback turtle stock. These habitats include foraging areas in the southern Pilbara, inshore inter-nesting areas near Onslow and the confirmation of foraging areas in the north Kimberley.
- Tracking flatback turtles from a newly established long-term monitoring site at Thevenard Island enables adjustment to monitoring design, and understanding pressures to turtles from this rookery.
- Large scale movements of turtles provides an opportunity to engage the interests of people from all walks of life. Partnerships with local staff, traditional owners and indigenous rangers enhanced education throughout local communities and schools while accessible data and media coverage increased engagement across the general public.

Future directions

- Turtle tracking will continue to answer specific management questions and gaps in biological and/or geographical knowledge.
- Research will continue into improving how transmitters are attached to flatback turtles.

The Western Australian Marine Monitoring Program

SP 2012-008

T Holmes, M Rule, K Bancroft, G Shedrawi, A Halford, A Kendrick, 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 marine fauna to facilitate and promote management effectiveness in the protection and conservation of marine biodiversity and related social values.

Progress

- An internal review into the scope and operations of the marine monitoring program continued during 2016/17 to ensure that it operates effectively and efficiently.
- Updated monitoring data was collected for fish, coral, seagrass, macroalgae, mangroves, little penguins, turtles 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 marine park coordinators on the condition of biodiversity assets and the significance of pressures acting on them to inform adaptive management strategies and Departmental reporting processes.
- Marine monitoring datasets continued to be placed on the Divisional CKAN data catalogue.
- The production of monitoring reports was revised in accordance with the internal review. A new series of detailed monitoring reports on marine reserves will be made available to the public, and will be revised

periodically. The first three of these new monitoring reports, on Jurien Bay Marine Park and the Ningaloo and Shark Bay marine reserves, are currently approaching completion.
- 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.
- Three scientific papers utilising Departmental monitoring data sets were published in in the journals *Methods in Ecology and Evolution*, *Limnology and Oceanography: Methods* and *Coral Reefs*. These papers were on the extraction of habitat complexity and coral cover from diver operated stereo-video (stereo-DOV) imagery and identifying the influence of local hydrodynamics on coral vulnerability at Ningaloo Marine Park.
- 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 strategic plan

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
- Develop a Strategic Plan for the NWSFTCP to outline the scientific, management and communication activities over the next five years in the context of long-term goals.

- Establish the governance arrangements for the NWSFTCP.

Progress

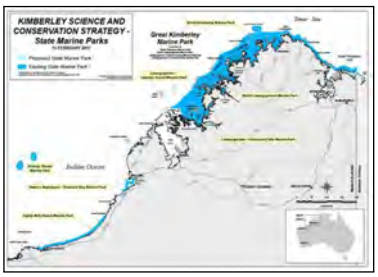
- The NWSFTCP Strategic Conservation Plan has been completed and management actions are already underway to meet the milestones of the plan.
- A Strategic Communication Plan has been developed and is being implemented, including the establishment of a project website.
- The governance arrangements were finalised with the establishment of the NWSFTCP Advisory Committee and Scientific Panel. Both meet at least twice annually to receive information and provide advice to both the operations team and the Director General.

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.

Future directions

- Deliver the program according to the NWSFTCP Strategic Conservation Plan.
- Develop and implement a detailed monitoring plan.
- Report all future work through a new over-arching SPP focused on coordination and delivery of the NWSFTCP and smaller SPPs and collaborative agreements.



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 Parks and Wildlife 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 focussed 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 underway between 2012 and 2017 and will 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 Parks and Wildlife 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 approved for six projects and have been received and reviewed for an additional four projects, with approval pending minor editing.
- The results of fourteen projects have been presented in lunch time seminars and at meetings with the KMRP advisory group to share key research findings with stakeholders and discuss how the science may best be used by managers.
- Two regional briefings have been held to share research findings with regional staff for their use in operational management of the Kimberley marine reserves.
- Several opportunities have been supported to expand research projects at the request of regional staff (e.g. extending dugong aerial surveys and historical sediment assessments).
- A working group comprising representatives from seven indigenous communities has been formed to lead the Indigenous Knowledge project. This group has held three workshops and a series of on-country meetings to work towards achieving project objectives for integrating indigenous knowledge with western science 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

- Review final reports and develop management implications and tools jointly with lead scientists and managers.
- 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.
- Produce a KMRP Node final report as a synthesis of the research program into a regional perspective on marine biodiversity, ecosystem function and the pressures on these values which can be mitigated by management.
- Coordinate an end of program symposium to showcase the science and generate further discussion and understanding around program synthesis and the application of the new findings to management action.

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. DEC 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). DEC 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 DEC management policies, practices and actions. The latter element will become an increasing focus of this project as the research program progresses to completion in 2010, and the final synthesis report is developed for the wrap up of WAMSI in December 2011. As such, both communication and data management are critical elements in knowledge transfer and uptake and are being addressed through this program.

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 the 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 leaned can be applied to future WAMSI and Parks and Wildlife research programs.

Progress

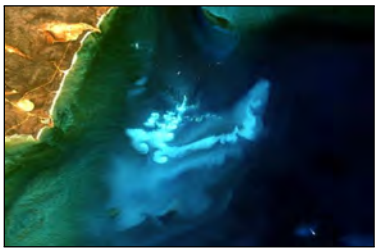
- A final report reviewing the effectiveness of knowledge uptake from the Ningaloo Research Program was received and approved in September 2016, and a publication on the review was published in the*Journal of Environmental Management.*
- A seminar on the review was presented to Parks and Wildlife staff to discuss research findings and recommendations to improve knowledge exchange in future large research programs.
- Based on early findings, the review project was extended to include an evaluation of changes to social capital associated with the Ningaloo Research Program. This research, which involved surveys of the Exmouth and Coral Bay communities, is now complete and a draft manuscript is being prepared.

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.

Future directions

- Completion of the final report on changes to social capital stemming from the Ningaloo Research Program.
- Give final seminar on knowledge exchange, including implications for social capital.
- Manuscript submission based on social capital and marine research, using the Ningaloo Research Program as a case study.



Effects of the Gorgon Project dredging program on the marine biodiversity of the Montebello/Barrow Islands marine protected areas

SP 2010-008

S Field, R Evans, G Shedrawi

Context

The Gorgon Project (GP), which is based on Barrow Island, is one of the world's largest natural gas projects and the largest single-resource natural gas project in Australia's history. 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 GP included a dredging program that involved the removal and dumping of approximately 7.6 M 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 protected areas (MBIMPA). 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 of the MBIMPA.

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 MBIMPA.
- Determine the cause/s of any changes in the condition of the above communities, with particular focus on dredging, dumping and resuspension 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 MBIMPA.
- Assess the nature and extent of the impacts from the Gorgon dredging program on the social assets of the MBIMPA.

Progress

- A paper assessing coral health and disease from digital photographs and in-situ surveys that examined the utility of identifying coral disease from digital images, was published in *Environmental Monitoring and Assessment*.
- A paper on effects of dredging on critical ecological processes for marine invertebrates, seagrasses and macroalgae was published in *Ecological Indicators*.
- Data from the project was contributed to a study investigating how gradients of disturbance and environmental conditions influence coral community structure.

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 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

- Complete the Gorgon MER Phase One final report, publications and data archiving.
- Incorporate Gorgon MER Phase Two monitoring into the marine monitoring program.

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

SP 2009-013

M Rule, A Kendrick

Context

The 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. The benthic invertebrate community of the inlets has been described from surveys conducted in 1984 and 1987. The fauna was found to be 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. Little is known, for example, of how the fauna varies in response to the seasonal hydrological cycle.

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 the WNIMP and more broadly across temperate estuarine marine protected areas.

Progress

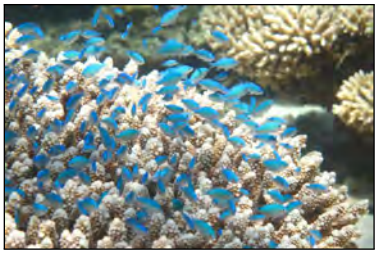
- A collaborative Parks and Wildlife/Edith Cowan University student camp was held at WNIMP in April 2017, with Coastal and Marine Management course students undertaking a study of bivalve and fish communities in the estuary. Data were collected and provided to Parks and Wildlife to assist future research planning.
- Analysis of spatial and temporal benthic invertebrate and fish community data is continuing.

Management implications

- As benthic invertebrates are a KPI for this marine reserve, knowledge of spatial and temporal patterns in their distribution is important in relation to understanding the condition of this community in relation to the influence of natural processes and possible anthropogenic impacts. This study will also assist the implementation of long-term benthic invertebrate community monitoring at WNIMP.

Future directions

- Analyse several large datasets and write papers.



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

- Data from this project has contributed to several national and international research collaborations. This required development of methods to make Departmental data compatible with information collected from other parts of the world. Methodological comparisons were conducted in the field and correction factors developed to make fish data collected by our research and monitoring comparable with larger data sets.
- Effects of the 2016 El Niño event on corals in parts of the Kimberley and Ningaloo regions relative to other parts of Australia were documented. A paper has been published in *Nature.*
- Data from long term monitoring of Ningaloo coral communities and information on local water movement were used to identify reefs resilient to effects of climate change. A paper was published in *Coral Reefs.*
- Investigation of effects of fishing pressure on fish biomass and associated ecosystem functions was undertaken. A paper has been published in *Current Biology.*

Management implications

- Environmental disturbances associated with climate change pose a major threat to the long term conservation of coral reefs in Western Australia's marine parks and reserves. Understanding which environmental factors promote recovery on coral reefs allows managers to identify which reefs are more likely to persist over time.
- This research has identified where effects of fishing and climate change are most severe and factors that make some reefs more resilient than others to these effects.

Future directions

Continue assessments of how frequently coral bleaching is occurring and how this effects fish communities.

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

SP 2009-002

M Rule, A Kendrick, J Huisman, B French

Context

The 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 the spatial and temporal patterns in the composition of intertidal reef communities in the MMP, SIMP and NCMP, including the proposed northern extension to the 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

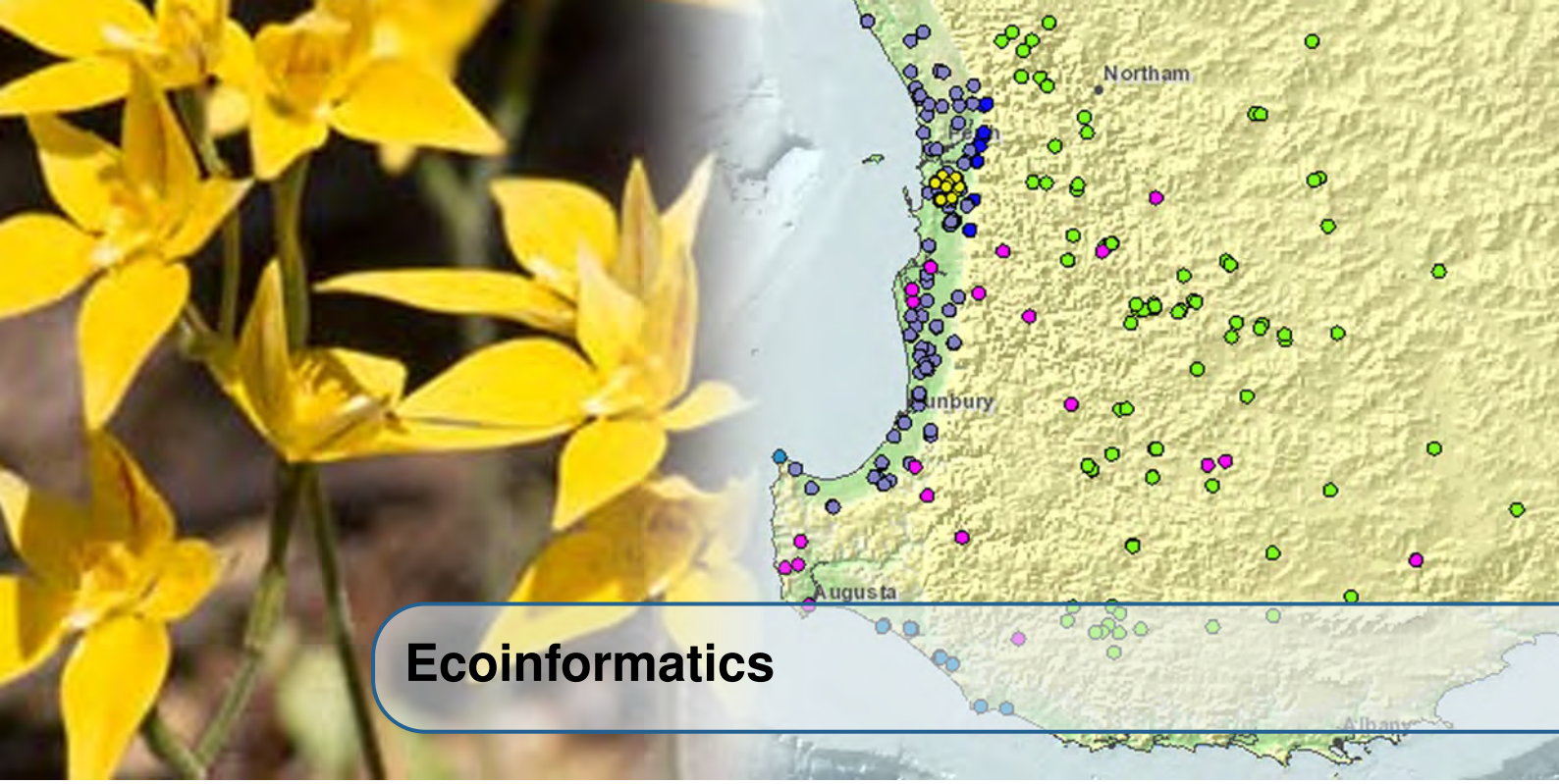
- A manuscript describing differences in community structure on intertidal granite and limestone substrates at NCMP is being prepared.
- An expert workshop of local experts was organised and hosted by Parks and Wildlife. Scientists from CSIRO, The University of Western Australia, Western Australian Museum, Curtin Uni and Parks and Wildlife met to determine the status of research on the flora and fauna of limestone platforms from Cape Leeuwin to Shark Bay. Workshop participants shared their research findings, discussed potential collaborations, and considered future research priorities that would best inform conservation management.

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 to ascertain the conservation significance of these habitats and assist the implementation of long-term intertidal reef monitoring and management in marine parks and reserves.

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 in MMP and SIMP will be completed.
- Intertidal reef surveys at NCMP will continue.



Ecoinformatics

Program Leader: Paul Gioia A major role of the Ecoinformatics Unit is to manage and make available the digital biodiversity assets of the Science and Conservation Division. 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 the division, 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.

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 datasets are often irreplaceable. A corporately accessible database is required to capture bilogical 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 datasets, and increases accessibility of ecological data to departmental users and systems.

Progress

- The Kimberley Islands Biodiversity Survey dataset was incorporated into BioSys.
- Improvements have been made to enable datasets of any structure to be incorporated into the system.

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.

Future directions

- Undertake further testing using other priority datasets supporting a variety of business processes, and initiate a program for preparing and importing legacy datasets.
- Implement integration with downstream applications such as NatureMap, and improve user experience for defining and modifying datasets.

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 re-architecture is continuing, making data more easily available to other applications and systems requiring authoritative taxon name information.
- Minor bugs have been fixed and enhancements implemented as required.
- 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.

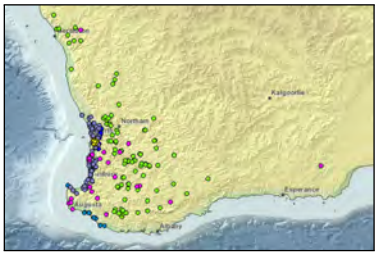
Management implications

- 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

- Continue with re-architecture of WACensus to make data available to external applications.
- Make use of Australian Plant Census and Atlas of Living Australia online web services to reduce double-handling by Western Australian Herbarium staff.



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 datasets 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

- Datasets from major surveys were added, including the 2009 Kimberley Islands biodiversity survey, and the Nullarbor and Kimberley rainforest regional surveys conducted in 1984 and 1990, respectively.
- A variety of additional datasets were added, including a focus on island records (Pilbara islands fauna data, and weeds on Western Australian islands), *Banksia* woodlands on the Swan Coastal Plain, bird records from Kellerberrin, and a survey of Kimberley limestone ranges to complement the 1990 Kimberley rainforest survey.
- Occurrence records now total 5.1 million, an increase of over 900,000 records (21%).
- The number of datasets warehoused has increased from 69 to 85 (23%).
- An additional 211 new registrations were recorded, bringing the total from 2153 to 2364, a 10% 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 Goldfields and Pilbara region biological surveys.
- Improved integration with BioSys, the Western Australian Biological Survey Database.
- Implementation of a new Rangelands theme.

External Partnerships

Partners	Project Title	External Funding	Parks and Wildlife Involvement
ANSTO radionuclides	Investigation of radionuclide contamination at Montebello Islands to understand implications for turtles and researchers	$20,000	S Whiting
ARC Linkage, Australian National University, CSIRO, Alcoa	Genomics for climate adaptation in *Eucalyptus* foundation species	$375,000	M Byrne
ARC Linkage, 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
ARC Linkage, 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 (over three years)	I Radford
ARC Linkage, 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 over three years	D Coates, M Byrne, M Millar
ARC Linkage, Murdoch University	The ecology of parasite transmission	$150,000 over three years	A Wayne, K Morris
ARC Linkage, The University of Western Australia, Botanic Garden and Parks Authority	Is restoration working? An ecological assessment	$520,000	D Coates, M Byrne, MA Millar
ARC Linkage, 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	Parks and Wildlife Involvement
ARC Linkage, 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 over three years	D Pearson
ARC Linkage, University of Tasmania, Department of Primary Industry - New South Wales, Department of Environment, Water and Natural Resources - South Australia, Smithsonian Institute (USA).	Functional responses of rocky reef communities to effects of fishing and other anthropogenic stressors.	$900,000	T Holmes
ARC Linkage, University of Western Sydney, Murdoch University	Do hotter and drier regions harbour adaptive variation for climate change	$281,505	M Byrne, R Mazanec
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 (2016-2017)	J Dunlop, K Morris, S van Leeuwen
Atlas Iron, Main Roads Western Australia	Ecology and management of the Pilbara olive python	$70,000	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
Atlas of Living Australia, Council of Heads of Australasian Herbaria, CSIRO	Collections Community Developer and Botanical Collections Community Coordinator	$87,000	J Huisman, R Butcher, B Richardson
Australian Biological Resources Study	Cryptic speciation in Australian *Cleome*(Cleomaceae) and resolution of generic status.	$15,000	M Byrne, D Coates
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 foraging areas in the Kimberley	$1,000,000	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 over three years	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 Transect Network, CSIRO, Terrestrial Ecosystem Research Network, Adelaide University, AusPlots	South-Western Australian Transitional Transect	$12,000	S van Leeuwen, N Gibson, M Byrne
BHP Billiton	Biological survey of Walyarta	$50,000	A Pinder, K Quinlan, A Markey
BHP Billiton	Identification botanist position at the Western Australian Herbarium	$105,000	J Huisman, S Dillon
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

Partners	Project Title	External Funding	Parks and Wildlife Involvement
Bushfire and Natural Hazards CRC	Bushfire and Natural Hazards CRC	Nil	L McCaw
CSIRO and independent scientists	Explaining and predicting the occurrence of night parrots (*Pezoporus occidentalis*) using GIS and ecological modelling	$38,000	AH Burbidge
CSIRO, Australian SuperSite Network, Terrestrial Ecosystem Research Network, National Research Infrastructure for Australia	Great Western Woodlands SuperSite	Nil	S van Leeuwen
CSIRO, Mt Gibson Mining	Invasive *Passiflora foetida* in the Kimberley and Pilbara: understanding the ecology, threat and exploring solutions	Nil	S van Leeuwen
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, 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, University of Tasmania, Edith Cowan University	Climate-resilient vegetation of multi-use landscapes: exploiting genetic variability in widespread species	$298,000	M Byrne, C Yates, B Macdonald, R Binks, L McLean
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	$70,000	K Quinlan, A Pinder, M Lyons, 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, Bush Heritage Australia	Biological survey of the Birriliburru Indigenous Protected Areas	$25,000	S van Leeuwen, K Quinlan, M Langley, N Gibson, M Cowan, A Pinder, L Gibson
Charles Sturt University	Introduced predator interactions with an endangered native predator, the Pilbara northern quoll	$78,000 over 3 years	J Dunlop
Chevron - Gorgon Net Conservation Benefit, James Cook University, ARC Centre of Excellence for Coral Reef Studies	Decision support system for prioritising and implementing biosecurity on Western Australia's islands	$5,000,000 over five years	C Lohr, K Morris, L Gibson
Chevron - Net Conservation Benefit	Cat eradication on Dirk Hartog Island	$3,000,000 (2012-2017)	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

Partners	Project Title	External Funding	Parks and Wildlife Involvement
Chevron	Translocations of mammals from Barrow Island: offset program	$9,500,000 (2009-2019)	K Morris, N Thomas, C Sims, J Angus, S Garretson, M Blythman
Curtin University, Australian Institute of Marine Science	Mapping species distributions using towed video and BRUV	Nil	S Wilson
Curtin University, The University of Western Australia, University of Saskatchewan	Protecting the safe havens: will granite outcrop environments serve as refuges for flora threatened by climate change?	$330,000	C Yates, M Byrne
Department of Agriculture and Food, Department of State Development, Department of Water, Kimberley Land Council, Nyamba Buru Yawuru Ltd, Yamatji Marlpa Aboriginal Corporation.	La Grange Irrigate Agriculture Project area bilby and conservation significant flora surveys	$600,000	M Byrne, S van Leeuwen, M Dziminski, M Lyons, A Markey
Department of Fisheries, CSIRO, Australian Institute of Marine Science, Curtin University	Connectivity of coral trout populations between individual reefs on the Rowley Shoals	Nil	AR Halford
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	D Algar, M Onus, N Hamilton, M Johnston
Department of the Environment and Energy, Scientec Pty Ltd	PAPP toxicosis and cat bait pellet development	Nil	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 Life Project	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, T Tucker, S Whiting
Environmental Consultants Association of Western Australia, Environmental Institute of Australia and New Zealand, Office of the Environmental Protection Authority	Best practice for fauna impact assessment	Nil	S van Leeuwen, AH Burbidge, M Cowan, K Morris, M Williams, N Thomas
Fortescue Metals Group, BHP Billiton	Floristic survey of the Fortescue Marsh	$245,000 (2014-2016)	S van Leeuwen, M Lyons, A Markey
Fortescue Metals Group, Millennium Minerals, Roy Hill	Ecology and management of the bilby in the Pilbara	$215,000 (2015-2016)	M Dziminski, F Carpenter, K Morris, S van Leeuwen
Fortescue Metals Group	Vegetation map reconciliation and compilation for the Hamersley and Fortescue subregions in the Pilbara	$160,000 over three years	S van Leeuwen, B Bayliss
Fortescue Metals Group	Fortescue Marsh feral cat baiting project	$700,000 (2012-2016)	D Algar, S van Leeuwen

Partners	Project Title	External Funding	Parks and Wildlife Involvement
Geocatch, Edith Cowan University, Department of Fisheries	The long-term monitoring of seagrass communities in Geographe Bay	$10,000	M Rule
James Cook University	Human impacts on coral reef communities	Nil	S Wilson
James Cook University	Establishing baselines and assessing vulnerability of commercially harvested corals across northern Australia	$150,000	S Wilson
Landgate	Western Australian State Government Data Catalogue	$12,000	F Mayer
Main Roads Western Australia, Kimberley Land Council, Rangelands NRM Western Australia, Nyamba Buru Yawuru Ltd	Conservation and management of the bilby (*Macrotis lagotis*) on the Dampier Peninsula, Kimberley.	$600,000 over three years	M Dziminski, F Carpenter, K Morris, S van Leeuwen
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, Caring for our Country	Fish populations and invasive species of the Vasse-Wonnerup Ramsar site	$215,000	J Lane, A Clarke
Murdoch University, Curtin University	Evidence based management of foxes adjacent to turtle beaches in Western Australia	$300,000	S Whiting
Murdoch University, South West Catchments Council	Fish and invertebrates of the Vasse-Wonnerup Ramsar site	$14,000	J Lane, A Clarke
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, Bureau of Meteorology	Evaluation of bushfire spread simulators used in Australia	Nil	L McCaw
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
Parks Australia and other Christmas Island land management organisations	Christmas Island cat eradication	$250,000 (2015-2020)	D Algar, N Hamilton
Pilbara Corridors, Rangeland NRM Western Australia	Biological survey of Fortescue River catchment clay pans	$350,000 over two years	A Pinder, M Lyons, K Quinlan

Partners	Project Title	External Funding	Parks and Wildlife Involvement
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
Rhodes College Tennessee, St John's University New York, USA	Phylogenetics and floral symmetry development of the core Goodeniaceae	Nil	K Shepherd
Rio Tinto, BHP Billiton	Seed collection zones for the Pilbara	$600,000	M Byrne, S van Leeuwen, D Coates
Rio Tinto, Queensland Herbarium, Darwin Herbarium	Resolving the systematics and taxonomy of *Tephrosia* in Western Australia	Nil	R Butcher, S van Leeuwen
Rio Tinto	Introduced predator control and baiting program - Yarraloola	$3,000,000 over five years	K Morris, R Palmer, J Angus, H Anderson, K Rayner, S Garretson
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	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
Terrestrial Ecosystem Research Network	AEKOS: ecoinformatics facility and development of ecological databases and portals	Nil	P Gioia
The University of Western Australia, Australian Institute of Marine Science, CSIRO Marine and Atmospheric Research, Department of Fisheries, Western Australian Museum	Temporal and spatial variation in coral cover on Western Australian reefs	Nil	S Wilson, Professor S Pratchett (James Cook University), G Shedrawi, S Field
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

Partners	Project Title	External Funding	Parks and Wildlife Involvement
University of Adelaide	Wetland biological survey and monitoring: rotifer and cladoceran identifications	Nil	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 Swansea, Wales	Carbon dynamics and forest fire.	Nil	L McCaw
West Australian Biogeochemistry Centre, CSIRO Earth Science and Resource Engineering, BHP Billiton	Hydrogeochemistry of Walyarta Springs	$120,000 over two years	J Rutherford
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	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 (IGEM)	Nil	S Field, F Mayer
Western Australian Marine Science Institute	Project 1.2.3: Saltwater crocodiles (*Crocodylus porosus*) in the north-west Kimberley	$30,000	A Halford
Western Australian Marine Science Institute	WAMSI Project 1.2.2. Key biological indices required to understand and manage nesting sea turtles along the Kimberley coast	$1,200,000	S Whiting, T Tucker
Western Australian Museum	NatureMap: data sharing and joint custodianship	Nil	P Gioia
Western Australian Museum	Woodside Collection Project (Kimberley)	Nil	J Huisman

Student Projects

Parks and Wildlife Officer	Student	Academic	Project Title	Duration	Page
D Algar	S Comer (PhD)	Dr P Speldewinde (The University of Western Australia), Dr D Roberts (The University of Western Australia)	Ecology of the feral cat (*Felis catus*) in coastal heaths of the south coast of Western Australia	2014 – 2021	115
D Algar	N Dybing (PhD)	Dr P Adams (Murdoch University)	Parasites and diet of feral cats and rodents on mainland Western Australia and offshore Islands (Christmas Island and Dirk Hartog Island)	2012 – 2016	115
A.H. Burbidge	M Lohr (PhD)	Dr R Davis (Edith Cowan University)	Responses of southern boobooks (*Ninox boobook*) to threatening processes across urban, agricultural and woodland ecosystems.	2017 – 2019	116
A.H. Burbidge	N Leseberg (PhD)	Dr J Watson (University of Queensland), Dr S Murphy (Australian National University), A/Prof R Fuller (University of Queensland)	Ecology and conservation biology of the night parrot	2017 – 2019	116
N Burrows, K Morris	M Wysong (PhD)	Dr E Ritchie (Melbourne University), Prof R Hobbs (The University of Western Australia)	The ecology and interactions of dingoes and feral cats in the arid Rangelands of Western Australia	2012 – 2016	117
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	117

Parks and Wildlife Officer	Student	Academic	Project Title	Duration	Page
M Byrne	J Bruce (MSc)	Prof P Horwitz (Edith Cowan University), Dr A Koenders (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	118
M Byrne	N Delnevo (PhD)	Prof W Stock (Edith Cowan University), Dr E van Etten (Edith Cowan University)	*Conospermum undulatum*: insights into genetics and ecology of an endangered species	2017 – 2019	118
M Byrne	A Lullfitz (PhD)	Prof SD Hopper (The University of Western Australia)	Vegetation responses to Noongar land management practices in old and young landscapes	2014 – 2018	119
D Coates	R Dillon (PhD)	Dr R Standish (The University of Western Australia), Prof M Waycott (The University of Adelaide)	Mating systems, reproductive output and progeny fitness of translocated plant populations compared to wild populations.	2017 – 2019	119
D Coates	L Monks (PhD)	Dr R Standish (The University of Western Australia)	Factors affecting the success of threatened flora translocations	2016 – 2019	120
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 re-vegetated land	2017 – 2017	120
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	121
R Davis	T Hammer (PhD)	Prof L Mucina (The University of Western Australia), Dr K Thiele (Eubio Consulting)	Phylogeny, systematics and evolution of the Australian arid-zone *Ptilotus*	2015 – 2018	121
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, *Dasyurus hallucatus*	2017 – 2017	121
J Dunlop	H Moore (PhD)	Dr L Valentine (The University of Western Australia), Prof D Watson (Charles Sturt University), Dr D Nimmo (Charles Sturt University)	The influence of invasive predators and fire regimes on northern quolls in the Pilbara	2017 – 2019	122
R Evans	M Moustaka (BSc (Honours))	Dr T Langlois (The University of Western Australia)	The impacts of suspended sediment on fish assemblage structure in northwest Australia	2016 – 2016	122

Parks and Wildlife Officer	Student	Academic	Project Title	Duration	Page
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Student Project Reports

Ecology of the feral cat (*Felis catus*) in coastal heaths of the south coast of Western Australia

STP 2016-018

Scientist(s): D Algar
Student: S Comer (PhD)
Academic(s): Dr P Speldewinde (The University of Western Australia), Dr D Roberts (The University of Western Australia)

This 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, and building 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 over 100 stomach samples feral cats collected from nature reserves and national parks across the south coast region have been analysed, and samples collected from these and cats from Dirk Hartog Island and Fortescue Marsh for stable isotope analysis. Feral cats have been tracked on conservation properties managed by Bush Heritage in the Gondwanalink Fitz-Stirling corridor. Analysis of GPS collar data collected from 51 cats collared in south coast reserves, and from nature reserves and Bush Heritage properties in the Fitz-Stirling's corridor is progressing, with data from collars being assessed for habitat use and resource area dependency. Funding has been sought for additional collars for deployment in the Gondwanalink Landscape. Twenty-four monitoring sessions have been completed for use in prey availability modelling, and these data are now being analysed.

Parasites and diet of feral cats and rodents on mainland Western Australia and offshore Islands (Christmas Island and Dirk Hartog Island)

STP 2012-202

Scientist(s): D Algar
Student: N Dybing (PhD)
Academic(s): Dr P Adams (Murdoch University)

Feral cats and black rats are renowned for their potential to act as reservoirs for disease of conservation and zoonotic significance. Research has focussed on developing methodologies for the molecular detection of a series of significant pathogens suspected or previously reported on the Western Australian mainland and Dirk Hartog and Christmas Islands including *Bartonella* spp., *Leptospira* spp., *Trypanosoma lewisi* and *Leishmania* spp.

The last year has involved the final writing up of the PhD thesis titled "Invasive animals and the Island Syndrome: parasites of feral cats and black rats from Western Australia and its offshore islands". The thesis was submitted for examination and has subsequently been returned with corrections. A third chapter has been published in a peer reviewed journal: *Vector Borne Zoonotic Diseases.* A fourth chapter describing the helminth parasites of feral cats and black rats on Christmas Island has been submitted to *Australasian Journal of Environmental Management*. Another chapter is to be submitted to *Austral Ecology* as part of an invited papers edition once thesis corrections have been made. This chapter it tentatively titled "What did the feral cat drag in? Feral cats, helminths and the Island Syndrome."

Responses of southern boobooks (*Ninox boobook*) to threatening processes across urban, agricultural and woodland ecosystems.

STP 2017-052

Scientist(s): A.H. Burbidge
Student: M Lohr (PhD)
Academic(s): Dr R Davis (Edith Cowan University)

The southern boobooks (*Ninox boobook*) is a cryptic species which may be declining in the south western Australia as a consequence of anthropomorphic impacts. This project aims to investigate boobook decline and identify possible causes, such as secondary poisoning from anticoagulant rodenticides ingestion, across of series of landscapes impacted differently by human activity.

A review of the use of anticoagulant rodenticides in Australia is nearing completion. 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 has been conducted for 55 samples and analysis for an additional 19 specimens is currently being finalised. Genetic analysis at nine microsatellite markers has been completed for 96 individuals. Analysis for approximately 90 additional samples is ongoing. 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.

Ecology and conservation biology of the night parrot

STP 2017-051

Scientist(s): A.H. Burbidge
Student: N Leseberg (PhD)
Academic(s): Dr J Watson (University of Queensland), Dr S Murphy (Australian National University), A/Prof R Fuller (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.

The ecology and interactions of dingoes and feral cats in the arid Rangelands of Western Australia

STP 2014-016

Scientist(s): N Burrows, K Morris
Student: M Wysong (PhD)
Academic(s): Dr E Ritchie (Melbourne University), Prof R Hobbs (The University of Western Australia)

This project explored evidence for top-down suppression of an exotic mesopredator, the feral cat *Felis catus*, by a native apex predator, the dingo *Canis lupis dingo* in an arid rangeland environment in Western Australia (Matuwa). It examined the spatial dynamics of feral cat and dingo distributions and activities and the potential for competition between them for shared prey. By analysing both spatial and dietary dimensions of dingo and feral cat interactions the research allowed for a very detailed characterization of this intraguild relationship.

There was no strong evidence for dingo suppression of feral cats in this study system. Low dietary overlap between the two species suggests limited interspecific competition, which may also facilitate their observed spatial overlap. Feral cats may show a preference for grasslands but whether this is driven by avoidance of dingoes or by the occurrence of other resources such as prey warrants further investigation. This knowledge obtained in this project contributes to the conceptual development of top-down ecological theory and increases the understanding of how apex predators and smaller mesopredators relate to one another in their environment.

This PhD project has been completed.

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: i) signals of adaptive genetic variation; and ii) phylogeographic patterns for four plant species endemic to Western Australia. The research will determine whether generalist and host-specific parasitic species have similar adaptive variation and phylogeographic patterns compared to sympatric non-parasitic plants. Finally, 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.

The research proposal has been completed. Field sites are being identified and fieldwork is expected to commence in the second half of 2017.

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): Prof P Horwitz (Edith Cowan University), Dr A Koenders (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 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.

Fieldwork to investigate morphology and to collect genetic and herbarium specimens is underway. DNA extractions of the populations already sampled have been undertaken using a modified CTAB method. The proposed research has been presented as both a poster and three oral presentations at two conferences and two Western Australian Wildflower Society meetings.

Conospermum undulatum: insights into genetics and ecology of an endangered species

STP 2017-028

Scientist(s): M Byrne
Student: N Delnevo (PhD)
Academic(s): Prof W Stock (Edith Cowan University), Dr E van Etten (Edith Cowan University)

Anthropogenic loss and fragmentation of natural habitats is now at unprecedented levels, making land use change one of the most important drivers affecting biodiversity. Within the southwest Western Australian biodiversity hotspot, the Swan Coastal Plain bioregion was historically cleared for agriculture and forestry, and is now experiencing extensive land clearing for urbanisation. *Conospermum undulatum* is a plant species endemic to 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.

The present PhD project aims to address key research gaps in our knowledge of the rare *Conospermum undulatum* through an integrated study of the genetic diversity, contemporary pollen-mediated gene flow, pollinator behaviour, pollen limitation, and reproductive success of this plant species over its entire range. It also aims to genetically confirm the presence of hybrids and to assess whether genetic introgression is posing a risk to the species. The experimental design and methodology have been completed. Ecological surveys and samples collection will commence during the 2017 flowering season.

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 SD 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 tu*ber 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, *Platysace deflexa* and *Platysace trachymeniodes*. To date, a total of 793 individuals of *Platysace deflexa*,*P. trachymenioides*, *P. effusa*, *P. maxwellii*, *P. compressa* and *P. juncea* have been sampled at 109 sites located in inland areas southwest of a line from Northampton to the Cape Arid National Park. Sequencing trials have identified three noncoding chloroplast DNA regions for analysis, trnS-trnG52S, trnV-ndhc and psbD-trnT. DNA extraction, polymerase chain reaction and sequencing has been carried out on approximately half of selected sampled individuals.

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): Dr R Standish (The University of Western Australia), Prof M Waycott (The University of Adelaide)

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 investigate relationships between reproductive output, progeny performance and mating system variation; 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 outcomes for not only assessing long term translocation success, but for also improving translocation design and establishment technologies.

Field studies have commenced with cones and measurements collected from two of five *Banksia brownii* populations and seed extraction is underway. A pilot study examining pollinator type using exclusion cages is being undertaken on one montane and one lowland population of *B. brownii*. A full experiment will be conducted next flowering season. Preparation for field trials has commenced with 1,500 *B. brownii* seeds weighed, plated and germinated and site preparation finalised. Selection for the second study species, *Acacia rhetinocarpa* has also been finalised and field work planned for early August.

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 ongoing management and recovery programs. The aim of this study is to investigate factors affecting success of plant translocations, in order to inform future translocations and ultimately help to prevent the extinction of plant species. Aspects of translocation success to be investigated include undertaking a meta-analysis of past plant translocations in Western Australia to provide an insight into factors that contributed to successful outcomes; assessing genetic diversity and mating systems of translocated compared to the wild, source populations of *Lambertia orbifolia*; 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 undertaking a cross pollination study of the annual, *Schoenia filifolia,* to evaluate whether the genetic composition of the founder populations contributes to translocation success.

Field work has commenced and sampling has been undertaken. leaf material was collected from *Lambertia orbifolia* for the genetic diversity study, detailed monitoring of *Acacia cochlocarpa* subsp. *cochlocarpa* was undertaken for the PVA study, and genetic material and seed was collected from *Schoenia filifolia* for the cross pollination study.

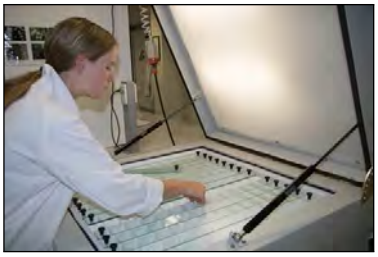
Evaluation of Gondwana link restoration projects with reference to mycorrhizal communities in remnant and re-vegetated land

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 re-vegetation 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 re-vegetation practices in the future, and provide suggestions for the best chance of reinstating or maintaining natural mycorrhizal communities.

To date soil and root samples have been collected from three Gondwanalink sites: Monjebup North; Peniup; and Chingarrup. Isolation of mycorrhizal fungi has commenced from the root samples, and seed from *Acacia cyclops* and *Melaleuca acuminata* has been germinated for the growth experiments using site-collected soils.



Effects of climate change on the Australian native grass *Neurachne alopecuroidea*: 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 wouth-west of Western Australia. It is an ideal species for investigation of the impacts of a warming 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.

Preliminary results demonstrate that *N. alopecuroidea* germinates well at temperatures above 25^{o}C, but reduced moisture availability has a large impact on percentage germination and time to 50% germination. The effects of moisture and temperature vary across populations of the species.

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), Dr K Thiele (Eubio Consulting)

Ptilotus is a genus of annual and perennial herbs and shrubs common 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, *Dasyurus hallucatus*

STP 2017-046

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

This project will use DNA forensic methods in order to examine questions about northern quoll paternity,

sexual selection and spatial ecology on the Pilbara mainland and at a Pilbara island site. The project aims to: (i) determine difference in the paternity of northern quoll pouch young from mainland and island populations; (ii) investigate the male characteristics that female quolls prefer in their mates, such as body mass or scrotal size (mate choice / sexual selection); (iii) investigate the mating systems of northern quolls; and (iv) investigate how mating systems influence the spatial ecology and dispersal of young quolls.

The results of this study will have applications in: (i) predicting how northern quoll populations respond to future disturbances such as cane toad invasion; (ii) providing data, such as the ideal male:female breeding ratio, to support captive breeding programs should they be required in the future; and (iii) providing information for environmental consultants, biologists and resource development companies, ensuring the protection of the northern quoll population. To date, DNA from 110 quoll pouch young samples has been extracted, and genotyping and data analyses are well underway.

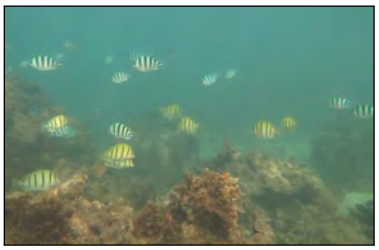
The influence of invasive predators and fire regimes on northern quolls in the Pilbara

STP 2017-045

Scientist(s): J Dunlop
Student: H Moore (PhD)
Academic(s): Dr L Valentine (The University of Western Australia), Prof D Watson (Charles Sturt University), Dr D Nimmo (Charles Sturt University)

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 (i) calculate monitoring effort required to effectively assess occupancy changes in northern quoll populations; (ii) assess how factors, such as fire frequency, habitat structure and predator densities, influence quoll occupancy; and (iii) elucidate the potential impacts of introduced predators on quoll trophic positioning as well as temporal behaviour.

Significant headway has been made in assessing occupancy changes and identifying factors influencing occupancy. Pre-existing live trapping data has been used to model the effectiveness of the current cage trapping method at detecting quoll presences across a number of known populations. The results of this model will now be compared with the effectiveness of remote sensing camera trap data, to assist in developing cost-effective standardised northern quoll monitoring protocols based on detection and occupancy probabilities. Remote sensing cameras have been established at 120 sites have been established across the Pilbara aimed at detecting both quolls and introduced predators, such as wild dogs/dingoes and feral cats. Over two six-month trapping periods these cameras will provide an estimated 36,000 trapping nights worth of data, as well as crucial insight into the way in which quolls interact with both predators and their environment.



The impacts of suspended sediment on fish assemblage structure in northwest Australia

STP 2016-006

Scientist(s): R Evans
Student: M Moustaka (BSc (Honours))
Academic(s): Dr T Langlois (The University of Western Australia)

Anthropogenic impacts are dramatically increasing the amount of sediment in coastal waters. The detrimental impact of sediment loading on coral reefs is well known, yet the impacts on fish are poorly understood. The reefs off Onslow in Western Australia's Pilbara region provide an opportunity to assess the impact of varying levels of suspended sediment on fish communities in the natural environment. This study aims to examine the impact of different levels of turbidity and light attenuation on the fish community assemblage, including various feeding guilds.

The main finding of the project was that sediments have a negative impact on two important trophic groups of fish, the herbivores and zooplanktivores. The project has been completed and a manuscript is in preparation for submission to the journal *Marine Pollution Bulletin*.

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 de Bettignies (The University of Western Australia), Dr T Wernberg (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 explore the biogeographical patterns of coral distribution from tropical into temperate areas; to establish a point of reference for future change; 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 to examine the environmental suitability of temperate reefs as refugia for corals under elevated ocean temperatures on progress required.

All fieldwork has now been completed and data analyses is underway.

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 with the overall aim to investigate green turtle foraging ecology and energetics. Specific aims include: investigating diet and variation in diet between size/age classes using stable isotope analysis, and identifying movement of foraging and nesting green turtles using satellite tags and using Dynamic Energy Budget (DEB) modelling to investigate allocation to growth and reproduction throughout the lifecycle.

Progress this year included a field trip to collect eggs and samples for stable isotope analysis and the completion of respirometry and incubation experiments on eggs. Samples have been prepared for stable isotope analysis.

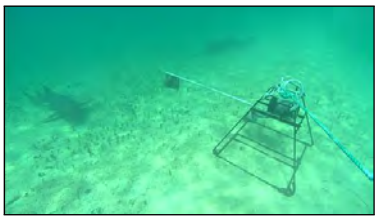
The assessment of ecosystem risk in *Banksia* woodlands of the Swan Coastal Plain, Western Australia

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 WA biodiversity hotspot and have been subjected to extensive clearing. These *Banksia* woodlands are now listed as a threatened ecological community (TEC) at a Commonwealth level. There are numerous floristic community types within *Banksia* woodlands, of which several are threatened. Swan Coastal Plain floristic community type 20a (SCP20a) (*Banksia attenuata* woodlands with species rich dense shrublands) is listed as a TEC in WA. The threatening processes of *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 research gaps for improving the understanding of *Banksia* woodlands 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 aims to integrate spatial analysis of environmental factors with biological data to identify predictive capability. The study also aims to conduct an assessment of threatening processes to determine the relative impact of each as drivers of change to *Banksia* woodlands. Finally, the study proposes to evaluate the effectiveness of the recent IUCN Red List of Ecosystems (RLE) approach for assessing risk to *Banksia* woodlands, with reference to alternative approaches for determining thresholds of concern. The experimental design and methods have been developed with initial meta-analysis and new floristic surveys to commence the second half of 2017.



Baited video, but not diver video, detects greater abundance of legal sized target species within Sanctuary Zones at Ningaloo

STP 2017-049

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

Assessment of the role of sanctuary zones in marine parks 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 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 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 fishing. The thesis has been submitted and a manuscript is being prepared for publication.

Distribution and behaviour of two morphologically distinct shark species in the Ningaloo Marine Park, Western Australia

STP 2017-048

Scientist(s): T Holmes
Student: I Lindgren (MSc)
Academic(s): Dr T Langlois (The University of Western Australia), D McLean (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 (BRUV) to investigate factors that influence the distribution of grey reef (*Carcharhinus amblyrhynchos*) and white tip (*Triaenodon obesus*) sharks at Ningaloo. Both species were more abundant as distance further 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 within the Ningaloo Marine Park, Western Australia

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 and 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 within the Ningaloo Marine Park. This study has been completed and a manuscript is being prepared for a peer-reviewed journal.

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. The thesis has been submitted and papers from this study are being prepared.

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): Dr J Conran (The University of Adelaide), Prof M Waycott (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 understand the nature of the relationship between the plant and the insect, to improve knowledge of the poorly known life history of the insect, study the genetic structure within and between populations of both species, and investigate whether the two organisms have co-evolved.

Field work was carried out in Western Australia in 2015 and 2017, plants and insects were maintained in Adelaide, and extensive genetic analysis performed. Some planned aspects of the work were modified as a result of difficulties in translocating insects, and also with a realisation of the importance of fire in the ecology of these organisms. Data analysis is being undertaken.

Recovery of karri forest after an extreme wildfire in Northcliffe.

STP 2016-016

Scientist(s): L McCaw
Student: H Etchells (BSc (Honours))
Academic(s): Dr P Grierson (The University of Western Australia)

This project seeks to enhance understanding of the ecological response of karri forest to bushfire, focusing on the recovery of mature karri and marri trees and seedling recruitment and survival following the large O'Sullivan bushfire of February 2015. The study will test the hypotheses that with increasing fire severity, overstorey trees will exhibit higher levels of seedling recruitment and lower levels of epicormic resprouting, and that high severity fire will result in a more homogenous understorey dominated by plant species that are ephemeral or have attributes that make them successful as disturbance opportunists. Nine study sites were established sampling unburnt forest and forest burnt at low and high severity, as determined by crown scorch and defoliation. At each site, all trees within a 30 m x 30 m quadrat were measured for stem diameter and crown condition, and understorey species composition determined in five 4m^2 quadrats. Soil samples were also collected for assay of carbon, nitrogen and carbon isotope signatures. The thesis was submitted for examination in November 2016.

A further field trip was undertaken in March 2017 to re-sample vegetation response and soil chemistry. The intention is to expand the study to a PhD examining how vegetation recovery influences re-colonisation of burnt areas by quokka.

Ecological genetic assessment of *Hakea laurina* in restoration sites compared with remnant bush

STP 2016-010

Scientist(s): D Coates, M Millar
Student: R Fernandes (MSc)
Academic(s): Dr G Oostermeijer (University of Amsterdam)

This project is part of a larger ARC Linkage Project entitled 'Is restoration working? An ecological assessment' that 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. 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.The aims of this project are to assess and compare insect flower visitors, seed weight, levels of genetic diversity and the mating system for restored and natural remnant populations of *Hakea laurina*.

Field work was undertaken at four sites (two revegetation and two natural remnants). Insect flower visitors observations and collections were undertaken, and seed collections were made to determine seed weight as a measure of reproductive fitness. Levels of genetic diversity and mating system for the populations were determined using 12 microsatellite markers.Results show that remnant populations have significantly greater insect abundance. Restored populations showed greater levels of allelic genetic diversity and this was also true for restoration progeny at Chereninup. Outcrossing rates were high but lower in restored compared to remnant populations, especially at Peniup. There was positive correlation between seed weight and outcrossing rate. The project has finished and a publication is being prepared.

Genetic assessment and population viability analysis of translocations of black-flanked rock wallabies (*Petrogale lateralis*) 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 (*WA Wildlife and Conservation Act*). Populations are restricted to suitable rocky habitat in a number of disjunct locations including the Little Sandy Desert, Cape Range, Wheatbelt and Barrow and Salisbury Islands. A small (two animals) population was recently re-discovered in Kalbarri National Park. This site was also part of a planned reintroduction 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 a further two translocations are planned for 2017 and 2018.

This project will evaluate the 2016 and 2017 rock-wallaby translocations from a genetic perspective and provide 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 will evaluate: (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 will also provide recommendations on the numbers of animals needed to be genetically-representative of the source populations and/or the Wheatbelt as a whole.

To date, DNA extractions and microsatellite genotyping has been completed on both the 2016 and 2017 translocated animals, as well as the male from the extant Kalbarri population. Analyses on the genetic diversity and representativeness of the translocated populations is underway and a population viability model has been developed. Rock wallaby scats have been collected and analysed from the Mt Caroline wheatbelt population for a pilot study investigating the effectiveness of scat DNA analysis as a monitoring tool.

Genetic assessment of a reintroduced population of brushtail possum (*Trichosurus vulpecula*) at Matuwa (Lorna Glen)

STP 2017-024

Scientist(s): K Ottewell, M Byrne
Student: L Semple (BSc (Honours))
Academic(s): Dr H Simianer (University of Goettingen)

This study focused on a declining population of south-western Brush-tailed Possums (*Trichosurus vulpecula hypoleucus*) to assess genetic variability and inform future management strategies. Between 2007 – 2009 a total of ninety-five individuals of *T. v. hypoleucus* were translocated from four extant populations within Western Australia to the Matuwa Kurrara Kurrara Indigenous Protected Area in central Western Australia. The latest monitoring survey at Matuwa in 2015 indicated the minimum number of animals known to be alive as 25, though capture-recapture analysis estimated that the total population size may be up to 50 animals. The reasons for this decline are unknown. Mortality of reintroduced radio-collared individuals was largely undetermined but there were no records of individuals being predated by cats. However, during trap monitoring of reintroduced possums, many individuals were considered to be under-weight suggesting the possibility of resource limitation in the period soon after translocation. In addition, this current small population may now be vulnerable to effects of reduced genetic variation and inbreeding.

This study investigated whether a lack of genetic diversity or presence of inbreeding could be contributing factors in the decline of the translocated population at Matuwa. Genetic diversity and inbreeding in the Matuwa population was compared to the original source populations to detect whether there has been a loss of diversity or increase in inbreeding. A population viability model was constricted for *T. v. hypoleucus* at Matuwa to investigate factors important for the long-term persistence of the translocated population.

Tissue samples from 146 animals were analysed using 13 microsatellite loci. Inbreeding was lower and heterozygosity was higher in the translocated Matuwa population than two source populations studied, highlighting the benefits of promoting outbreeding through the use of multiple source populations in translocations. However, allelic richness at Matuwa is low suggesting the impact of population bottlenecks on genetic diversity, which was supported by significant tests for genetic bottlenecks. Despite the genetic health of the population being stronger than predicted, this population is still threatened due to environmental factors. Population viability analysis suggests it is facing further declines within the next 10-15 years without future management of the site. Several management strategies are suggested including population supplementation and provision of artificial nest boxes. A manuscript has been prepared for submission to a peer-reviewed journal.

Ecological Responses of the northern quoll (*Dasyurus hallucatus*) to a large-scale feral cat baiting program in the western Pilbara region, WA.

STP 2017-047

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

This project builds on an existing large-scale feral cat baiting and northern quoll monitoring program in the Pilbara being undertaken in partnership with Rio Tinto. The broader aims of the project are to investigate the nature of feral cat and northern quoll interactions at the landscape scale, how northern quolls may benefit from annual feral cat control, assess the impact of the baiting program on the abundance of feral cats and 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 properties in 2016 and 2017 to calculate cat densities. Preliminary results from 2016 indicate a significant reduction in cat numbers across the baited property. Habitat surveys and description at each of the cat camera locations was been made. Demographic data has been obtained from three extended quoll trapping periods, hair and tissue samples have been collected for stress hormone analysis and genetic analysis, respectively. Development of monitoring approaches using GPS devices for northern quolls and feral cats, with the technology being novel in the case of feral cats.

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 in Moore River Nature Reserve and two new sites along the south coast (near Northcliffe and East Augusta). Western swamp tortoise gut contents were also obtained and biomass calculated. All samples have been processed. Analyses will commence shortly and will contribute to an assessment of the suitability of new translocation sites for the Western Swamp Tortoise along the south coast.

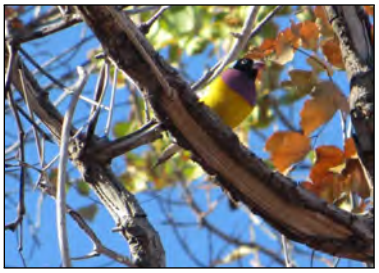
Is there a housing crisis in tropical savannas? Changing fire regimes, hollows and declining arboreal mammals.

STP 2017-017

Scientist(s): I Radford
Student: C E Penton (PhD)
Academic(s): Dr LA Woolley, Dr B Murphy (Charles Darwin University)

The project aims to determine whether contemporary fire regimes are threatening the viability of populations of savanna arboreal mammals. The study addresses five questions: (1) Is hollow abundance and diversity influenced by fire regimes? (2) What characteristics of trees are associated with different sized cavities? (3) What are the characteristics of tree hollows resulting in occupancy? (4) What is the frequency of hollow use? (5) Is arboreal mammal diversity and abundance influenced by the abundance and diversity of hollows?

Field work has commenced on Melville Island. Monitoring sites in CSIRO's Tiwi fire experiment will be used to place known arboreal mammal abundance within a landscape vegetation structure/hollow/fire regime context. Statistical modelling will be used to test for what environmental factors have the strongest influence on arboreal mammal abundance and diversity.



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)

This PhD project was set up to test for the effects of fire regimes on breeding and food resources of threatened Gouldian finch at known breeding sites near Wyndham in the East Kimberley. Breeding success data from 2007 through to 2015, fire scars data at breeding sites and across the region, annual *Sorghum* grass seed phenology, ecology and production/nutritional quality (main food resource for finches) was used to determine the impacts of fire regimes on finch feeding and breeding ecology.

The results of this project showed finches breed more successfully in years following fire at breeding sites, breed less successfully after frequent fires, breed more successfully in years with many regional fires and less successfully in years with large but few fires. *Sorghum* seeds have more nutritional value at sites which are recently but infrequently burnt, providing a mechanism for breeding site selection and success. Timing of early wet season rainfall, and not attributes of the fire regime appear to determine the timing of finch breeding.

Mammal declines in northern Australia: science for conservation and recovery

STP 2016-027

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

This project is part of a larger ARC program investigating the role of cats and fire regimes on mammal declines across northern Australia. The project included radio tracking of cat activity with respect to fire, a cat exclosure experiment, camera trapping in rocky and non-rocky habitats, mammal gene flow in rocky and non-rocky habitats

and radio tracking critical weight range mammals to determine habitat use under different fire regimes.

The results of the project showed that feral cat activity is greater in recently or frequently burnt open savanna habitats and in non-rocky habitats where reduced ground cover makes hunting easier. Small mammal numbers declined in open burnt habitats as a result of cat activity. Cats are capable of causing local extinction of small mammals in savanna habitats based on exclosure studies. Impacts of cats on mammals can be minimised by burning under conditions that favour less intense, smaller and more patchy fires. Impacts on mammals can also be reduced by minimising cattle disturbance of ground layer vegetation. Threatened mammals, including the golden backed tree rat and the scaly tailed possum, use a diverse array of habitat attributes to meet their resource requirements (e.g. nesting hollows, fruiting trees), and may utilise both recently burnt and long unburnt vegetation. Rocky habitats in the North Kimberley where patchy fire regimes occur encouraged gene flow among northern quoll populations, while open savanna habitats formed barriers to breeding and gene flow.

Evolution of C_4 photosynthesis in the genus *Tecticornia* at the anatomical and molecular levels

STP 2017-044

Scientist(s): T Macfarlane, KA Shepherd
Student: N Dakin (PhD)
Academic(s): Prof G Kadereit (Mainz University, Germany), Dr M Ludwig (The University of Western Australia)

Tecticornia (family Chenopodiaceae) is a genus of succulent, salt-tolerant plants. The genus includes two species identified as using the C_4 photosynthetic pathway and 39 species currently categorised as C_3 plants. A number of species are endemic to Western Australia, where they play a key ecological role in salt-affected areas. *Tecticornia* species are difficult to identify, and have low genetic diversity. The relationships between species are not clear, and current phylogenies are unresolved. This study aims to investigate the steps in the evolution of C_4photosynthesis in the genus *Tecticornia* at the cell, protein and transcript levels. This project also aims to resolve relationships between species, and identify any potential C_3-C_4 intermediate species in the genus.

Genomic DNA has been extracted from dried herbarium tissue and the ETS region was amplified from 65 *Tecticornia* species, and the sequences determined. ETS sequences were used to construct maximum likelihood and Bayesian trees. Additional ITS sequences were also obtained, and added to the ITS data previously obtained. Additional ITS and ETS sequences were provided from chloroplast genome sequencing of *Tecticornia* species completed by Andrew Hall and Prof. Ian Small, as part of another project. ETS and ITS phylogenetic trees showed similar topology, and combined trees showed greater resolution of species compared to previous studies. The ETS and ITS combined phylogeny resolved taxa into 12 strongly supported clades. However, the backbone of the phylogeny remains unresolved, and the relationships between these clades are not clear. The aim of constructing the phylogeny was to determine which C3 species are most closely related to the C4 *Tecticornia* species. The C4 species formed a highly supported clade.

Species delimitation and morphometric analysis of *Anthotium humile* and revision of the genus *Anthotium* (Goodeniaceae)

STP 2017-043

Scientist(s): KA Shepherd
Student: K Smith (BSc (Honours))
Academic(s): Dr P Grierson (The University of Western Australia)

The aim of this project is to investigate and compare patterns of molecular and morphological variation in *Anthotium humile* and the two phrase-named species *Anthotium*sp. Peaceful Bay and *Anthotium*sp. Darling Range, and through this determine: (1) whether these putative taxa warrant formalisation as taxa distinct from *A. humile*, and at what rank; and (2) whether further taxa need to be recognised within *A. humile*. Ultimately, this

project will provide a formal revision of the genus *Anthotium*, as well as a full morphometric assessment and an updated phylogeny of the genus. To fulfil these aims the variation between these three taxa will be quantified through Landmarking and Elliptic Fourier morphometric analysis (EFA) and phylogenetic and multivariate analysis of Sanger DNA sequences. In addition, this project will provide morphological descriptions of, and identification guides to, the taxa in question, to better enable further biological research in this genus. Both genetic and morphological variation will be considered against geographical location and environmental heterogeneity.

Molecular evidence based on cpDNA and nrDNA has been obtained from samples across 11 field sites. *Anthotium humile* separates into two clades, with one placed sister to *A. rubiflorum+A. odontophyllum* ('*aff humile*') while the other is sister to *A. junciforme* ('typical *humile*'). The two phrase-named species *Anthotium* sp.Peaceful Bay and *Anthotiu* sp. Darling Range are not genetically distinct from typical *Anthotium humile*. Detailed morphometric analyses are currently underway scoring qualitative and quantitative characters from the 52 individuals collected in the field and from specimens in the collection at the Western Australian Herbarium. Progress has also been made in preparing flower samples for imaging and subsequent Landmarking analysis using tpsDIG2 software.

Movement and demographics of the Reintroduced *Bettongia lesueur* (Burrowing Bettong or Boodie) within a feral proof enclosure at Matuwa (Lorna Glen) WA.

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 inform selection of release site, release strategies and predator management for planned wild translocations of boodies outside the fence in 2018. Similar monitoring of released boodies will compare movement patterns exhibited by translocated animals, to these baseline patterns of resident animals. The first field trip, collaring and monitoring boodies from one warren is underway. Habitat mapping has begun and additional warrens will be monitored over the next 7-8 months.

Diversity in the *Triodia basedowii* E.Pritz. species complex and its implications for the evolution of the Australian arid zone biota

STP 2015-013

Scientist(s): S van Leeuwen
Student: B Anderson (PhD)
Academic(s): Dr K Thiele (Eubio Consulting), Dr P Grierson (The University of Western Australia), Dr M Barrett (Botanic Gardens and Parks Authority)

This project has substantially resolved species limits in the difficult *Triodia basedowii* species complex, which has a centre of taxonomic diversity in the Pilbara and has previously posed intractable taxonomic problems for ecological survey, mine-site restoration and conservation planning. The project has: improved our understanding of the taxonomic, ecological and geographic limits of the named taxa *T. basedowii*, *T. lanigera*, *T. concinna* and *T. plurinervata*; resolved ready for formal naming the phrase-named species *T.*sp. Shovelanna Hill (S. van Leeuwen 3835), *T.* sp. Little Sandy Desert (S. van Leeuwen 4935), *T.* sp. Peedamulla (A.A. Mitchell PRP 1636), *T.* sp. Warrawagine (A.L. Payne PRP 1859) and *T.* sp. Pannawonica (B.M. Anderson & M.D. Barrett BMA 89);

and discovered and characterised three new species. All species will be formally described in a forthcoming taxonomic revision of the group. In addition, the project has provided new knowledge on the evolutionary history of the Pilbara and of arid Australia based on phylogenetic and biogeographic patterns in the species complex.

Stress and disease in critically endangered woylies (*Bettongia penicillata*)

STP 2014-010

Scientist(s): A Wayne
Student: S Hing (PhD)
Academic(s): Prof A Thompson (Murdoch University), Dr S Godfrey (Murdoch University), Dr E Narayan (Charles Sturt University)

Effective wildlife management requires an understanding of how animals cope physiologically with stress. When stressors are encountered, the hypothalamic pituitary adrenal (HPA) axis is activated releasing glucocorticoids, which can alter immune function and infectious disease dynamics. This project investigated the relationship between stress, immune function and parasite infection dynamics in woylies.

Woylies were trapped from wild populations, reserves and captivity with faecal and blood samples collected from over 300 individuals. Parallel parasitological and non-invasive endocrine analyses were performed to quantify endoparasites and faecal cortisol metabolites (FCM), end-products of HPA axis activation. An assay developed for human infants to assess innate immunity was also adapted for use in woylies. The novel results suggest that stress physiology and *Trypanosoma*infection status influence innate immunity. Collecting longitudinal field data, proximate factors that influenced woylie stress physiology, including season, sex, parasite status and body condition were identified. Woylies' response to translocation and a major bushfire that unexpectedly occurred at a field site was also examined. After translocation, FCM was significantly higher than before or at the time of translocation. However, the variation was noted in both translocated and resident woylies and FCM was not related to short-term changes in parasite infection dynamics. FCM was not significantly higher immediately after the fire, nor were there corresponding changes in parasite load or body condition compared to the months preceding the fire. It is suggested that woylies can maintain homeostasis at least in the period immediately after a fire provided they are managed appropriately. The project provides new knowledge on woylie stress physiology and highlights the value of innovative tools to advance woylie conservation as they continue to face stressors in the future.

Pathogen transmission in the critically endangered woylie: a community, population, and individual approach

STP 2014-009

Scientist(s): A Wayne
Student: K Jones (PhD)
Academic(s): Prof A Thompson (Murdoch University), Dr S Godfrey (Murdoch University)

Woylie populations (both wild and captive) are relatively small and isolated, making them potentially more susceptible to impacts of perturbations and pathogens. Indeed, infectious pathogens may have played a role the recent woylie decline. Thus, this project focuses on understanding woylie response to perturbations (specifically fire and reserve expansion) as reflected by changes in movement patterns, social structure, and health. GPS collars were used to monitor woylies in a predator-proof reserve, Whiteman Park, while concurrently collecting data on body condition and screening for a variety of parasites. Evaluation of changes in movement patterns and conspecific interactions (home range area/overlap, nest-sharing, contact) relative to these perturbations was made through a combination of more traditional statistics and social network analysis. Assessing longitudinal

trends in parasitism with respect to demographic factors and perturbations, enabled identification of potential risk factors for parasitism and how they might be impacted by perturbations. Fieldwork and laboratory work have been completed, and analysis and writing is underway.

Investigating the impact of polyparasitism in translocated woylies (*Bettongia penicillata*), 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 translocations impact the transmission of parasites in woylies and what consequences this has for translocated hosts and other cohabiting species. 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.

A new species of trypanosome (designated *T.* sp. ANU2; yet to be described) has been discovered, which appears to be host (woylie) and site specific (UWR). Identification of *T. vegrandis* in possums and *T. noyesi* in chuditch have been made for the first time. A new species of *Ixodes* tick has been published in the journal *Parasites and Vectors,*and is scientifically significant due to the host specific nature of this parasite and risk of co-extinction. Results obtained from this project have also contributed towards a third paper published in *Ecohealth* examining stress physiology and parasite infection parameters during translocation.

A comparative health and disease investigation in the woylie: captive vs free-range enclosure vs wild

STP 2013-016

Scientist(s): A Wayne
Student: K Skogvold (PhD)
Academic(s): Dr K Warren (Murdoch University), Dr S Vitali (Murdoch University), Dr C Holyoake (Murdoch University), Dr C Monaghan (Murdoch University)

This project contributes to the investigation of the role of disease in the declines and limited recovery of the woylie. An extensive assessment of the health and disease status of woylies in two wild populations in the Upper Warren region, the insurance population at Perup Sanctuary, and the former captive insurance population at Perth Zoo was conducted over a two year period from October 2010 to November 2012. Extensive data for baseline reference ranges for woylie health exists for analysis for future wildlife health work. Several disease agents previously identified as potential risk factors for woylie populations were assessed with the results combined in an infectious disease surveillance paper recently accepted for publication. The significant findings of the project were: zero prevalence of exposure to *Toxoplasma gondii* or Wallal & Warrego orbiviruses; a low prevalence of exposure to Macropodid herpesviruses; and detection of a novel gammaherpesvirus. The clinical significance of these herpesviruses to wild woylie populations remains unclear as the positive individuals did not demonstrate clinical signs of herpesviral diseases. Further monitoring for herpesvirus infections in the woylie will be important to inform disease risk analysis for the novel virus, and to determine temporal trends in herpesvirus activity that may relate to population health and conservation outcomes.

Analysis of the data is being undertaken for serum cortisol, faecal glucocorticoid, and hair cortisol as potential measures in woylie health assessment, specifically at a population level. In addition, anti-oxidant and vitamin levels have been determined in a subset of samples for potential analysis as a novel health assessment technique in wildlife.

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 in relation to their predation of turtle nests. 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.

Five foxes were trapped and collared near a major flatback turtle rookery at Mundanbullangana Station and their movements were tracked over nine months. The results showed seasonal movements associated with the turtle nesting season and the locations of dens containing mothers and pups. Trap cameras were also used to investigate the distribution and relative density of foxes.

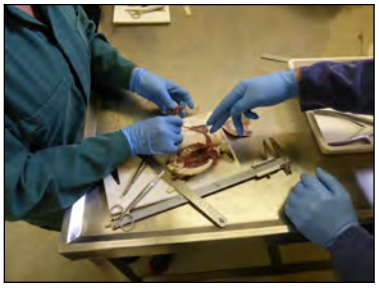
Understanding the early offshore movement of flatback turtle hatchlings and the effects of anthropogenic light

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 turtles in the wild. The aims of the 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 structures has on the predation rates of flatback hatchlings.

Successful laboratory and field experiments have been conducted. The laboratory experiments involved using a 30m long wave tank to help understand how hatchlings use wave and light cues to orientate in the water. The field experiments used acoustic tracking to follow hatchlings through the nearshore zone at Thevenard Island with and without the influence of artificial light.



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 (Murdoch University), 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. This project 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 have been obtained from nesting flatback turtles at Eighty Mile Beach and Thevenard Island. Necropsies were performed on numerous stranded turtles, including neonate flatback turtles found in a fish-kill event north of Broome and green and hawksbill turtles from various locations. Specialist parasitology training was provided by Dr David Blair who assisted in several necropsies at Murdoch University. Education messages about reducing plastics in our oceans were delivered after necropsies revealed high volumes of plastics in two green turtles.

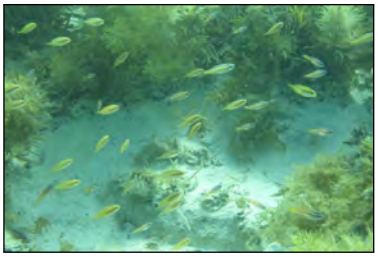
Predicting the effect of climate change on embryonic flatback (*Natator depressus*) and green (*Chelonia mydas*) sea turtles in the Kimberley region of Western Australia

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 on 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. Egg collections have been undertaken in the Kimberley and Pilbara. Laboratory work is now almost complete with model development currently underway to allow climate change impact prediction for flatback and green turtles. Collection sites have included Eighty Mile Beach, Lacepede Islands, Cape Domett and Thevenard Island.



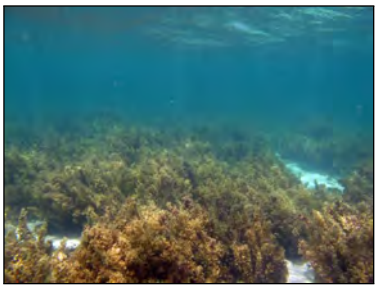
The significance of macroalgae to the diets of juvenile fishes and the ecosystem function of the Ningaloo Reef lagoon

STP 2016-007

Scientist(s): S Wilson
Student: C Desfosses (BSc (Honours))
Academic(s): Prof N Loneragan (Murdoch University), Dr H Lozano-Montes (CSIRO)

Structurally complex macrophyte patches within the Ningaloo lagoon act as nursery habitat for juvenile fish of ecological and fisheries importance. A strong association between juvenile fish and macrophyte habitat implies that fish feed on resources within these habitats, but there is little information on the diet of juvenile fish, especially in macroalgal habitats. This project will determine the importance of macroalgae and associated fauna to the diet of juvenile fishes at various macroalgal sites at Ningaloo Marine Park.

The results of the project show herbivorous rabbit and surgeon fish initially feed on filamentous algae but become increasingly reliant on macroalgae as they grow. Juvenile emperors feed on a range of invertebrates, including various types of worms, whilst goat fish fed mainly on crustaceans. Stable isotope analysis is required to determine if primary sources of energy in juvenile fish diets are from macroalgae and clarify the role of seaweeds in juvenile diets. It is intended to carry out stable isotope analyses and then prepare a manuscript 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.

Over the past year data has been collected on algal and fish communities from macroalgal patches around Coral Bay. A field experiment in which macroalgal structure has been altered at several patches has been established.

Can diver operated stereo-video surveys of fish be used to collect meaningful data on tropical coral reef communities for long term monitoring?

STP 2015-003

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

The condition of fish and coral communities are often monitored using digital imagery, but the techniques used to collect data differ. Fish data are collected using a forward-facing video, whist coral communities are typically monitored using cameras that face downward towards the substratum. This project collected forward- and downward-facing video and compared information to assess the compatibility of benthic/coral data collected using the different methods. Forward-facing video detected more vertically erect coral and canopy forming algae, but less turf algae and encrusting corals than downward-facing video. More coral genera could be identified and fewer corals were unidentifiable when using downward-facing video, suggesting a higher level of taxonomic resolution is achievable with this method. There were, however, strong relationships between the percentages of common benthos recorded by the methods. Thus, stereo video surveys for fish may be considered a potential technique for the description of coral reef benthos, but these methods are not necessarily suitable for monitoring of benthic community assemblages at high taxonomic levels. This project is now complete. The findings have now been published in a peer reviewed journal article (*Limnology and Oceanography Methods)* and Science and Conservation Division Information Sheet.

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. A manuscript documenting results from the meta-analysis has been submitted to the journal *Fish and Fisheries* and another manuscript describing a novel technique for collecting fish behaviour data and the utility of this measure as an indicator of fishing pressure has been submitted to the journal *Ecological Applications*.

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Summary of Research Projects

Biogeography

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
Swan, South West	Swan Coastal Plain, Jarrah Forest	Avon	Biological survey and conservation planning for the Swan Coastal Plain bioregion and adjacent scarps (Dandaragan, Darling and Whicher)	4
Kimberley	Victoria Bonaparte, Northern Kimberley, Dampierland	Rangelands	Kimberley islands biological survey	8
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Plant species richness and endemism within the south-western Australian Floristic Region	7
Goldfields, Wheatbelt, South Coast, Warren	Murchison, Avon Wheatbelt, Jarrah Forest, Mallee, Esperance Plains	Wheatbelt, Rangelands, South Coast	South-Western Australia Transitional Transect (SWATT)	3
All Regions	All IBRA Regions	All Regions	Western Australian flora surveys	5
All Regions	All IBRA Regions	All Regions	Western Australian terrestrial fauna surveys	6

Animal Science

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
Midwest	Carnarvon, Yalgoo	Rangelands	Cat Eradication on Dirk Hartog Island	10
Pilbara	Pilbara	Rangelands	Conservation and management of the bilby (*Macrotis lagotis*) in the Pilbara	14
South Coast, Warren	Jarrah Forest, Esperance Plains, Warren	South West, South Coast	Conservation of south coast threatened birds	20

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
Goldfields, Swan	Coolgardie, Swan Coastal Plain	Rangelands, Swan	Conservation of the graceful sun-moth	22
Pilbara	Pilbara	Rangelands	Decision support system for prioritising and implementing biosecurity on Western Australia's islands	12
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	24
Pilbara	Pilbara	Rangelands	Ecology and management of the northern quoll in the Pilbara	21
Wheatbelt	Avon Wheatbelt	Avon	Feral cat control and numbat recovery in Dryandra woodland and other sites	19
Pilbara, Swan	Pilbara, Swan Coastal Plain, Jarrah Forest	Rangelands, Swan	Genetic approaches for evaluating the contribution of the reserve system to fauna conservation	17
Kimberley, Pilbara	Northern Kimberley, Central Kimberley, Dampierland, Pilbara	Rangelands	Genetic assessment for conservation of rare and threatened fauna	15
South Coast	Jarrah Forest	South Coast	Gilbert's potoroo (*Potorous gilbertii*) recovery plan	25
Kimberley	Victoria Bonaparte, Northern Kimberley, Ord Victoria Plain, Central Kimberley	Rangelands	Impact of cane toads on biodiversity in the Kimberley	23
Pilbara	Pilbara	Rangelands	Improved fauna recovery in the Pilbara – Assessing the uptake of feral cat baits by northern quolls, and their associated survivorship	9
All Regions	Gascoyne	All Regions	Improving the use of remote cameras as a survey and monitoring tool	11
Goldfields	Gascoyne	Rangelands	Rangelands restoration: reintroduction of native mammals to Lorna Glen (Matuwa)	18

Plant Science and Herbarium

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
All Regions	All IBRA Regions	All Regions	Biodiversity informatics at the Western Australian Herbarium	34
Midwest	Geraldton Sandplains	Northern Agricultural	Climate change risks for biodiversity and ecosystem function in species-rich shrublands	29
Wheatbelt	Avon Wheatbelt, Swan Coastal Plain	Northern Agricultural, Avon, Swan, South Coast	Genetic and ecological viability of plant populations in remnant vegetation	44
Midwest, Goldfields, Wheatbelt, Swan, South Coast	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	49
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Herbarium collections management	32

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
All Regions	All IBRA Regions	All Regions	Interactive key and taxonomic studies of Myrtaceae tribe Chamelaucieae	28
South Coast	Esperance Plains	South Coast	Is restoration working? An ecological genetic assessment	27
Midwest, Wheatbelt, Swan, South Coast, South West, Warren	Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains	Rangelands, Northern Agricultural, Avon, Swan, South West, South Coast	Mating system variation, genetic diversity and viability of small fragmented populations of threatened flora, and other key plants of conservation importance	46
Kimberley	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	37
All Regions	Great Sandy Desert, Carnarvon, Gascoyne, Geraldton Sandplains, Avon Wheatbelt, Coolgardie, Swan Coastal Plain, Jarrah Forest, Hampton, Mallee, Esperance Plains, Warren	Rangelands, Northern Agricultural, Avon, Swan, South West, South Coast	Seed biology, seedbank dynamics and collection and storage of seed of rare and threatened Western Australian taxa	48
All Regions	All IBRA Regions	All Regions	Strategic taxonomic studies in families including Amaranthaceae and Fabaceae (*Ptilotus, Gomphrena, Swainsona*) and other plant groups	30
All Regions	All IBRA Regions	All Regions	Systematics of the triggerplant genus *Stylidium*	40
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	43
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	41
All Regions	Geraldton Sandplains, Avon Wheatbelt, Coolgardie, Swan Coastal Plain, Mallee, Esperance Plains, Warren	Northern Agricultural, Avon, Swan, South West, South Coast	Taxonomic studies on native and naturalised plants of Western Australia arising from biological survey	36
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Taxonomy of selected families including legumes, grasses and lilies	38
All Regions	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren	All Regions	Taxonomy of undescribed taxa in the Ericaceae subfamily Styphelioideae, with an emphasis on those of conservation concern	35
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	39

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
All Regions	All IBRA Regions	All Regions	The Western Australian Herbarium's specimen database	32
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	The Western Australian Plant Census and Australian Plant Census	31
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	42
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	47
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	45

Ecosystem Science

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
Warren	Jarrah Forest	South West	Burning for biodiversity: Walpole fine-grain mosaic burning trial	67
Goldfields, Wheatbelt, Warren	Avon Wheatbelt, Coolgardie, Mallee, Warren	Wheatbelt, Rangelands, South Coast	Climate-resilient vegetation of multi-use landscapes: exploiting genetic variability in widespread species	60
Kimberley	Victoria Bonaparte, Northern Kimberley, Ord Victoria Plain, Central Kimberley, Dampierland, Tanami, Great Sandy Desert	Rangelands	Development of an environmental risk strategy for sustainable agricultural planning in the Kimberley	53
Wheatbelt, Swan, South Coast, South West, Warren	Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Warren	Northern Agricultural, Avon, Swan, South West, South Coast	Do hotter and drier regions harbour adaptive variation for climate change?	51
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	66
Warren	Warren	South West	Fire behavior and fuel dynamics in coastal shrublands	57
Goldfields, Wheatbelt, South Coast	Yalgoo, Avon Wheatbelt, Coolgardie, Mallee	Wheatbelt, Rangelands	Fire regimes and impacts in transitional woodlands and shrublands	64
Pilbara, Midwest, Goldfields, Wheatbelt, South Coast, South West, Warren	Murchison, Geraldton Sandplains, Avon Wheatbelt, Coolgardie, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains	Wheatbelt, Rangelands, Northern Agricultural, South West, South Coast	Genetic analysis for the development of vegetation services and sustainable environmental management	71

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
Swan	Jarrah Forest	Swan, South West	Hydrological response to timber harvesting and associated silviculture in the intermediate rainfall zone of the northern jarrah forest	70
South West, Warren	Jarrah Forest	Swan, South West	Identification of seed collection zones for rehabilitation	65
South West	Warren	South West	Long term response of jarrah forest understorey and tree health to fire regimes	58
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
Kimberley	Northern Kimberley	Rangelands	North Kimberley Landscape Conservation Initiative: monitoring and evaluation	58
Goldfields	Gascoyne, Murchison	Rangelands	Project Rangelands Restoration: developing sustainable management systems for the conservation of biodiversity at the landscape scale in rangelands of the Murchison and Gascoyne bioregions–managing fire and introduced predators	68
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?	63
Warren	Jarrah Forest, Warren	South West	Responses of terrestrial vertebrates to timber harvesting in the jarrah forest	56
Warren	Warren	South West	Restoring natural riparian vegetation systems along the Warren and Donnelly Rivers	55
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	53

Wetlands Conservation

Parks and Wildlife 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	77
South West	Swan Coastal Plain, Jarrah Forest	South West	Hydrological function of critical ecosystems	73
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	75
Midwest, Wheatbelt, Swan, South Coast, South West, Warren	Murchison, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Esperance Plains, Warren	Wheatbelt, Northern Agricultural, Avon, Swan, South West, South Coast	South West Wetlands Monitoring Program (SWWMP)	76
All Regions	All IBRA Regions	All Regions	Taxonomy, zoogeography and conservation status of aquatic invertebrates	78

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
Warren	Warren	South West	Understanding peat wetland resilience: evaluating the impact of climate and land-use change on the hydrodynamics and hydrogeochemistry of peat wetlands in the Warren (Muir-Byenup) District	79
All Regions	All IBRA Regions	All Regions	Western Australian wetland fauna surveys	80

Marine Science

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
Swan	Swan Coastal Plain, Central West Coast	Swan	Access and human use at Penguin Island and related implications for management of Marine Park assets and visitor risk	87
Kimberley	Bonaparte Gulf, Kimberley, Northwest Shelf, Cambridge-Bonaparte, Canning, King Sound		Distribution and abundance estimate of Australian snubfin dolphins (*Orcaella heinsohni*) at a key site in the Kimberley region, Western Australia	85
Pilbara	Pilbara, Ningaloo	Rangelands	Effects of the Gorgon Project dredging program on the marine biodiversity of the Montebello/Barrow Islands marine protected areas	96
Pilbara	Pilbara, Pilbara (Offshore)	Rangelands	Habitat use, distribution and abundance of coastal dolphin species in the Pilbara	84
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	88
Pilbara	Ningaloo	Rangelands	Interactive effects of fishing and climate change on coral reef fish populations	98
Pilbara	Pilbara, Pilbara (Nearshore)		Long-term monitoring in the proposed Dampier Archipelago marine reserves	83
Kimberley, Pilbara	Northwest Shelf	Rangelands	North West Shelf Flatback Turtle Conservation Program strategic plan	92
Warren	WA South Coast	South Coast	Spatial and temporal patterns in benthic invertebrate communities of the Walpole and Nornalup Inlets Marine Park	97
Swan	Central West Coast	Swan	Spatial and temporal patterns in the structure of intertidal reef communities in the marine parks of south-western Australia	99
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	The Western Australian Marine Monitoring Program	91
Pilbara	Carnarvon, Pilbara (Nearshore)	Rangelands	The influence of macroalgal fields on coral reef fish	89
Kimberley	Northern Kimberley, Oceanic Shoals	Rangelands	Understanding movements and identifying important habitats of sea turtles in Western Australia	90
Pilbara	Pilbara, Ningaloo	Rangelands	WAMSI 1 Node 3: science administration, coordination and integration	95

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
Kimberley	Oceanic Shoals, Bonaparte Gulf, Kimberley, Northwest Shelf, Cambridge-Bonaparte, Canning, King Sound, Eighty Mile Beach	Rangelands	WAMSI 2: Kimberley Marine Research Program	93

Ecoinformatics

Parks and Wildlife 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	100
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Online GIS biodiversity mapping (*NatureMap*)	102
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Provision of authoritative names of Western Australian taxa	101

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