


Department of **Biodiversity, Conservation and Attractions**

GOVERNMENT OF WESTERN AUSTRALIA

**Biodiversity** and **Conservation Science**

# Biodiversity and Conservation Science Annual Report **2022–2023**

## Acknowledgement to Country

Our science is undertaken on the traditional lands of Aboriginal people. The Department of Biodiversity, Conservation and Attractions acknowledges the traditional owners of country throughout Western Australia and their continuing connection to the land, waters and community. We pay our respects to them, their culture and to their Elders past and present.

**Publication details**

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**Images**

**Front cover main photo:**
Sandplain vegetation in bloom at Zuytdorp, north of Kalbarri.
*Photo – Belinda Davis/DBCA*.

**Front cover top photos left to right:**
Remote sensing of fire grounds using multispectral drones. *Photo – Paul Rampant/DBCA*
*Caladenia procera* and its pollinator, *Zaspilothynnus nigripes*. Photo – *Belinda Davis/DBCA*
*Ecsenius alleni*. *Photo – Claire Ross/DBCA*
Forest monitoring. Photo – *Katinka Ruthrof/DBCA*

**Back cover top photos left to right:**
Underwater reef surveys. *Photo – Miecha Bradshaw/DBCA*
Grasswren release at Dirk Hartog Island National Park. *Photo – Michelle Hall/Bush Heritage Australia*
Plastics surveying at Bayswater Main Drain. *Photo – Zoe Beeson/DBCA*
Margaret River hairy marron crayling at Perth Zoo. *Photo – Tammy Goad/DBCA*

**Department of**

# Biodiversity, Conservation and Attractions

Biodiversity and Conservation Science

Annual Report

## 2022–2023

GOVERNMENT OF WESTERN AUSTRALIA

Department of **Biodiversity, Conservation and Attractions**

**Biodiversity** and **Conservation Science**

# Executive Director's Message

Our Biodiversity and Conservation Science report for 2022-23 highlights once again our delivery of the government's commitment to build and share biodiversity knowledge to support conservation and nature-based tourism in Western Australia. This is achieved through world-class applied science that informs conservation and management of our diverse plants, animals and ecosystems, and supports effective management of our parks and reserves, delivery of our fire program and engagement of visitors with our natural attractions.

Our consolidated Biodiversity and Conservation Science function continues to support business areas across the agency to achieve the department's Strategic Directions 2022-2025 by providing scientific excellence to support biodiversity conservation and nature-based tourism.

Biodiversity and Conservation Science provides innovative science through the technical expertise and capability of our science staff and the excellent support of our administration staff. The challenges we are facing as a society are impacting all of us and our staff continue to show their professionalism in the face of ongoing challenges. Our Conservation Science Forum in June focused on recognising and developing our people and knowledge leadership capabilities, fostering inclusion and diversity, supporting each other particularly when things seem overwhelming, and bringing open mindsets to maximise our collaborative and innovative approaches while celebrating how science supports delivery of key priorities of the department. I continue to be enormously proud of the Biodiversity and Conservation Science team and what we achieve together and with our partners.

Our collaborative and innovative science supports the current priorities of the department in providing knowledge and advice for delivering Plan for Our Parks, the Aboriginal Ranger program, joint management arrangements, response to climate change and renewed forest management. Other highlights of our scientific achievements this year include developing new remote area mangrove monitoring methods for use in the Kimberley Marine Parks; understanding the relationship between soil depth and tolerance to drought in jarrah; the first translocations of Gilbert's potoroo back to Two Peoples Bay National Park; the first listing of threatened ecological communities under the *Biodiversity Conservation Act 2016*; resolving the hybrid status of two threatened eucalypt species; the first successful captive breeding of the Critically Endangered hairy marron; establishing a 'living seawalls' trial in the Swan River; ingesting more than 2.8 million biodiversity recordsinto Dandjoo; conducting the first in-water coral and fish surveys at Bardi Jawi Garri Marine Park; and undertaking the largest threatened orchid translocation project in WA.

The Conferences of the Parties for Climate and Biological Diversity continue to identify the combined challenges of climate change and biodiversity decline, and the innovative science required to assist society in addressing these issues. We have new resources to work on these areas through a Climate Adaptation initiative, a changed focus on forest management in a drying climate, science to implement the Feral Cat Strategy, and biodiversity and spatial data to contribute to effective regional planning under the Native Vegetation Policy.

Our work is strengthened by our collaborations and partnerships both internally and externally. We continue to work collectively with conservation staff in the Parks and Wildlife Service, and at Kings Park and Botanic Garden, Perth Zoo and Rottnest Island. We engage with a wide range of external partners at universities, CSIRO, NGOs, WABSI, WAMSI and the National Environmental Science Program hubs. Co-supervision of many Honours, Masters and PhD students is evidence of our wide ranging science partnerships and we value these opportunities to work with and inspire the next generation of scientists.

We will continue to engage with all our partners to provide scientific excellence to support the department's functions and contribute to delivery of the biodiversity science priorities for Western Australia. The scientific information we generate and the biodiversity knowledge we provide is fundamental to ensuring the unique biodiversity we have around us is conserved, valued and appreciated through our natural attractions.

Dr Margaret Byrne
Executive Director, Biodiversity and Conservation Science
October 2023

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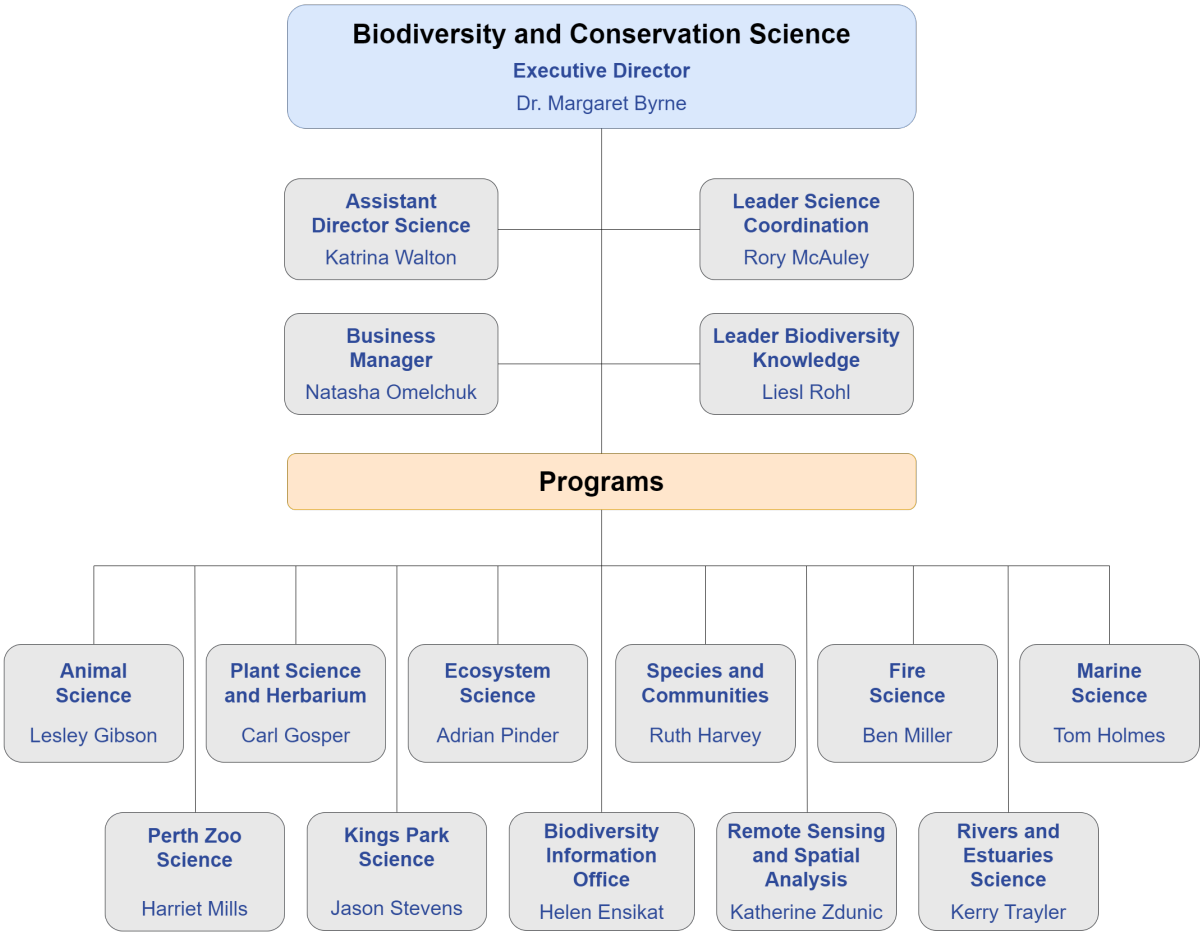
# Service Delivery Structure



# Biodiversity Information Office

**Program Leader: Helen Ensikat** The Biodiversity Information Office (BIO) has been established as custodian and manager of the Biodiversity Data Repository for the biodiversity data collected and used by the Western Australian community. BIO will mobilise biodiversity data from all environment-related sectors, including government, industry, and community organisations, promoting a culture of collaboration and seamless data sharing across government, industry, research and the community. Greater access to biodiversity data will increase knowledge of our biodiversity and support informed decision making. BIO enhances the capability of the WA public sector to deliver services to a diverse range of stakeholders, leading to the delivery of sound policy outcomes and evidence-based decision-making. BIO is a core component of the WA digital transformation initiative, delivering data services for digital transformation of environmental assessment and approvals system (Environment Online) that is led by the Department of Water and Environmental Regulation (DWER). BIO will provide seamless integration with Environment Online to ensure access to the best available information to inform decision making. BIO is part of the partnership between WA and the Commonwealth Department of Climate Change, Energy, the Environment and Water (DCCEEW) to deliver the Digital Environmental Assessment Program as an integrated digital environmental assessment system and biodiversity data repository.

## BIO data collation program

CF 2021-045

A Barker, H Ensikat, K Grogan, Z Huq, S Marcus, D Murphy, H Pichette, C Piper, N Panine, R Cechner

### Context

The data collation program of the Biodiversity Information Office (BIO) brings together data from a range of data sources and providers across industry, government, the public, research sectors and community organisations. BIO is initially focusing on high volume, high quality datasets, particularly those that are not easily accessible at present, driving a step-change in the availability of biodiversity data in Western Australia. The data is ingested into the platform after passing automated quality assurance checks, where it is mapped to the Darwin Core biodiversity data standard and undergoes a human-mediated quality control process before being released to users.

The initial datasets ingested into BIO's Dandjoo biodiversity data sharing platform have been sourced directly from industry, DBCA repositories, the Western Australian Museum, and regulators such as the Department of Water and the Environment (DWER). New data will continually be ingested, through future automated delivery from regulators and BIO's rolling program to identify and source other valuable datasets. This data collation

program will involve outreach to data custodians across all sectors, exploration of technologies to unlock data in pre-digital documents and ongoing monitoring of existing data to identify temporal and spatial gaps.

### Aims

- Provide users with access to a rich collection of high-quality datasets.
- Ingest new and up-to-date data over time.
- Enable access to previously undiscoverable and inaccessible datasets held by government and other sectors.

### Progress

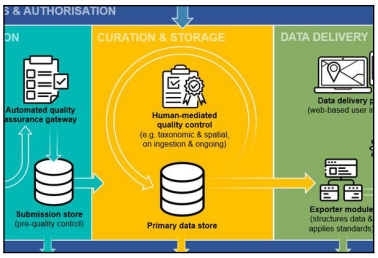
- Ingested over 1.8 million biodiversity records into Dandjoo; BIO's curatorial work on these records is driving a State-wide uplift in data quality, as many have not undergone curation since they were first collected.
- Progressed the acquisition of Western Australian biodiversity records from a range of international, State and Territory collections so they can be made available to Western Australian data users.
- Commenced a joint initiative with the Western Australian Museum to accelerate the databasing of a substantial backlog of collections records so these can be ingested into Dandjoo and support the Museum's research work.
- Continued collaboration with DWER on the one-off ingestion of historical environmental assessment data and re-engineering regulatory processes to allow for the automated ingestion of new data into the BIO platform.

### Management implications

- Access to a greater range of high-quality biodiversity data, including datasets that have not been available in the past, will support better-informed research and decision-making.
- Availability of up-to-date environmental assessment data, mapped to common standards and validated via the curation process, will ensure that environmental decisions are based on current and accurate information.

### Future directions

- Continue to ingest high quality datasets from within DBCA, the Western Australian Museum and DWER, and connect with potential data providers across all sectors to secure new data sets.
- Progress mapping of systematic survey data to the ABIS standard, enhancing the ways in which it can be ingested into, and visualised in, Dandjoo.
- Continue to co-design environmental assessment processes with DWER to embed data ingestion into the BIO platform including through pre-planning and application workflows for industry proponents.




## BIO biodiversity data platform

CF 2021-044

A Barker, H Ensikat, K Grogan, Z Huq, S Marcus, D Murphy, H Pichette, C Piper, N Panine, R Cechner

### Context

The Biodiversity Information Office (BIO) has developed Dandjoo, a central platform that makes Western Australian biodiversity data more easily discoverable, searchable, and accessible. Dandjoo was launched in mid-2022, and is being enhanced with a range of new features and refinements during 2022-23 and 2023-24. It has been designed to mobilise biodiversity data from all environment-related sectors, including industry, government and community organisations, and to support seamless data sharing across the public, private and research sectors and the broader community.

This work will drive improved regulatory decision-making, providing data for the State's forthcoming Environment Online portal to support digital transformation of environmental assessment and approval, and to other

State agencies to support evidence-based decision-making for better environmental outcomes. It also facilitates the automated exchange of biodiversity data between Western Australia and the Commonwealth to support decision-making at a national level.

**Aims**

- Allow users to easily discover, search, and access a range of Western Australian biodiversity data via a single platform.
- Provide streamlined access to biodiversity data for government agencies, including regulators, to enhance the quality and timeliness of decision-making.
- Develop a model that can be deployed in other States and Territories to automate the contribution of biodiversity data to an Australia-wide repository.

**Progress**

- Designed and tested a national best-practice methodology to allow users to securely access reduced-precision data about conservation listed species, with features using this approach to be rolled out in Dandjoo in the first half of 2023-24.
- Designed and commenced development of a wide range of enhancements and new features to be released progressively throughout 2023-24; these include expansion of search functionality, performance enhancements, and capability to display more complex data types, and are based on feedback from BIO's stakeholders.
- Collaboration continued with the Western Australian Museum, Western Australian Herbarium and other DBCA experts to ensure data in the platform remains up-to-date and robustly curated.

**Management implications**

- Increased data availability for industry and government will support environmental impact assessments and facilitate transparent and evidence-based environmental decisions.
- Access to a broader range of high-quality biodiversity data will expand research opportunities and enhance the quality of research outputs.
- Biodiversity conservation outcomes will be enhanced by more information on the geographic distribution of species in Western Australia, supporting the effectiveness of conservation programs and identification of knowledge gaps that will inform priorities for future data collection efforts.

**Future directions**

- Rollout of high-priority enhancements, allowing public users to safely access conservation listed species data with an appropriate level of precision, and to export unique species lists.
- Ongoing development of Dandjoo to provide additional functionality, including expanded search options, additional data fields, and enhanced handling of systematic survey data.
- Ongoing consultation with data users and data custodians across all sectors to prioritise future enhancements and refinements of the platform and future years.

# Animal Science

**Program Leader: Lesley Gibson** Applied research undertaken by the Animal Science Program seeks to understand the factors and processes critical for conserving 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.

## Distribution and conservation status of the heath mouse (*Pseudomys shortridgei*) in Western Australia

SP 2021-046

L Gibson, S Cowen, M Cowan

### Context

The heath mouse *Pseudomys shortridgei* (50-80g) is one of several native rodent species that have declined in distribution and abundance since European colonisation. Originally collected in 1906 near Pingelly in WA's wheatbelt, the heath mouse was thought to be extinct in WA until its rediscovery in 1987. Until 2019, the last confirmed record of the heath mouse in WA was in 2004, from Lake Magenta. Targeted surveys in 2019 resulted in their detection at two locations, confirming that the heath mouse was still extant in WA. Further surveys in 2020 failed to detect the species despite sampling in areas where they had previously been recorded. As there is evidence of a significant decline in the distribution and abundance, further targeted survey is critical to determine the current conservation status of the species in WA and inform recovery action.

### Aims

- Establish the current range and conservation status of heath mouse in WA.
- Identify populations that may be suitable for ongoing monitoring.
- Assess the possibility of sourcing heath mice for a captive breeding colony to provide founders for reintroductions.

**Progress**

- A targeted survey was undertaken in the western section of the Fitzgerald River National Park (Twertup Track) but failed to detect heath mice.
- A single heath mouse was captured during a further survey in Lake Magenta Nature Reserve, the first detection there since 2004.

**Management implications**

- Detecting the heath mouse again at Lake Magenta Nature Reserve suggests that it may be persisting in low numbers.
- In-situ conservation actions alone may not be adequate if the abundance of the heath mouse is determined to be critically low, and a captive breeding program may be required if animals can be captured.

**Future directions**

- Evaluate best approaches to maximise potential to detect heath mice.
- Undertake more intensive detection program at Lake Magenta with additional trapping and cameras.

## Genetics of Pilbara threatened bats

SP 2021-024

K Ottewell, R Sun, L Umbrello, D Prada, M Millar, R Shaw

**Context**

The orange leaf-nosed bat (*Rhinonicteris aurantia*) and the ghost bat (*Macroderma gigas*) were both once widespread across Australia but are now restricted to patchily distributed habitat across northern Australia. Isolated populations occur in the Pilbara bioregion, where a distinct form of the orange leaf-nosed bat is recognised (hereafter Pilbara leaf-nosed bat). Both species are considered to be declining in the Pilbara, being highly threatened by habitat loss through mining activity, and are consequently recognised as Vulnerable under State and Commonwealth environmental legislation. Genetic analyses are providing insight into landscape-scale and fine-scale patterns of genetic structure and connectivity in these species. The development of novel genetic techniques for non-invasive monitoring of ghost bats is providing rich insights into roost occupancy patterns and animal movement. Further research is required to address priority knowledge gaps for the species, including estimation of population size and identification and characterisation of critical habitat for each species.

**Aims**

- Understand the historical and contemporary genetic diversity and landscape-scale genetic structure of Pilbara bat species.
- Understand the fine-scale patterns of genetic connectivity of bat populations and sex-biased dispersal.
- Undertake SNP genotyping of non-invasive samples for genetic monitoring of ghost bat populations.
- Undertake development and refinement of mark-recapture analyses to assist development of standard monitoring protocols.
- Integrate genetic, spatial and distributional data to identify and understand critical habitat for Pilbara bat species.

**Progress**

- Mitochondrial and microsatellite analysis indicates very low genetic structure in the ghost bat with higher connectivity of populations in the western Hamersley Ranges and the Chichester Range, than with the eastern Hamersley Ranges.
- Eight genetic monitoring reports for ghost bats have been completed for industry.

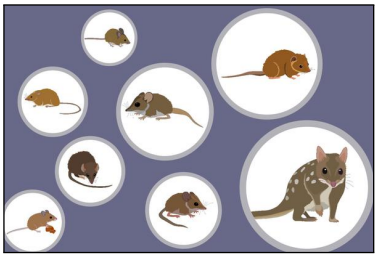
- A literature review of survey methods and management approaches for the ghost bat has been submitted to the *Journal of the Royal Society of Western Australia*.
- Assessment of the use of alternative mark-recapture approaches for non-invasive genetic monitoring has identified that both spatial and non-spatial mark-recapture models are suitable to estimate the abundance of ghost bats across temporal samples.
- A draft manuscript describing the development and validation of the ghost bat MassArray SNP genotyping panel is being finalised.
- A draft report on the integration of genetic IDs from microsatellite and SNP genotypes for the ghost bat is being finalised.
- Assembly of the ghost bat genome is being revised based on updated methods.
- Occurrence records for the ghost bat and the Pilbara leaf-nosed bat have been cleaned and spatial layers obtained to undertake species distribution modelling to assess core and foraging habitat for each species.

**Management implications**

- Genetic analysis of non-invasively collected samples and refinement of robust mark-recapture protocols for the ghost bat, will assist in monitoring of abundance and population trajectories, enabling better assessment of development impacts and/or mitigation approaches for the species.
- Species Distribution Models (SDM) will assist in identification of critical roosting and foraging habitat for both bat species and provide a guide for targeted surveys.
- Genetic monitoring is providing insight into ghost bat spatial ecology and temporal cave use, which has informed classification of ghost bat critical habitat and development of guidelines for minimising mining impacts.

**Future directions**

- Complete draft manuscript on population genetic structure of ghost bats and submit manuscript on ghost bat MassArray SNP genotyping panels.
- Continue with ghost bat genetic monitoring projects as requested.
- Finalise report on mark-recapture approaches for ghost bats and prepare manuscript.
- Further refine ghost bat genome and transcriptome assemblies and undertake genome annotation.
- Complete SDM for ghost bat and Pilbara leaf-nosed bat roosting and foraging habitat.



## Building resilience to change for mammals in a multi-use landscape: identifying refugia and landscape connectivity for small mammals in the Pilbara

SP 2021-008

K Ottewell, L Gibson, M Byrne, J Kinloch, K Zdunic, B Huntley

**Context**

To promote species' resilience over vast landscapes, long time-scales and under current rates of environmental change, it is essential for best-practice conservation strategies to: (i) identify historical refugia, areas that offer temporal and climatically stable habitat that species can retreat to, persist in and expand from under changing environmental conditions; (ii) protect key habitat in species' current distributions; and (iii) promote population connectivity to maintain metapopulation viability and to retain species' evolutionary potential.

Spatio-temporal landscape genetics, combined with Species Distribution Modelling (SDM), offers a novel approach to multi-species conservation planning. This project will provide current and historical insight into how small-medium sized mammals use the Pilbara landscape, providing information for conversation actions and habitat management. Therefore, this project is significant in bringing together key government and industry stakeholders engaged in conservation management in the Pilbara. Furthermore, the framework developed for integrating these findings into conservation priorities will be applicable for conservation management, globally.

### Aims

- Locate core habitat and connectivity pathways (corridors) for species under current environmental conditions by modelling habitat suitability and contemporary gene flow.
- Locate key areas for persistence under changing climatic conditions by inferring locations of evolutionary refugia from population genomic data and spatial modelling of range dynamics under historical and predicted future environments.
- Identify strategies to enhance and protect these areas for optimal combinations of threatened and non-threatened species conservation.

### Progress

- Based on the core habitat of 19 species (identified with SDM), maps of species richness were generated for the Pilbara. Three guilds of small-medium-sized mammal species were identified, reflecting species with preferences for rocky habitat, high aridity, or spinifex and weathered areas. This work is in preparation for publication.
- Genetically informed connectivity modelling across eight small-medium-sized mammal species was completed, revealing that dispersal in rocky specialists was less restricted than for generalists and sand specialists across the Pilbara landscape. For the latter, the Fortescue Marsh is a major dispersal corridor.
- A landscape and population genetics paper on Pilbara northern quolls (*Dasyurus hallucatus*) was published in the journal *Conservation Biology*, and provides tools for conservation decision-making.
- A comparative landscape genetics paper on three Pilbara small mammal species that evaluates different statistical approaches and genetic marker types to provide methodological guidance was published in the journal *Ecology and Evolution*.

### Management implications

- Identification of environmental variables that underpin core habitat for Pilbara small-medium-sized mammal guilds is providing insight into species ecology and enables conservation efforts to be guided toward areas that benefit multiple species.
- The Fortescue Marsh is indicated as a major dispersal corridor for generalist and sand specialist small-medium sized mammals suggesting targeted conservation efforts in this region will assist in maintaining connectivity and gene flow amongst populations of these species.
- The generation of high-resolution genetic data for eleven mammal species, including four EPBC-listed threatened species, has assisted in the detection of historical refugia, key dispersal corridors, genetic diversity hotspots and potentially locally adapted populations that may act as foci for conservation protection.
- The spatial-genetic maps generated in this project are being made available to a range of end users to assist in various conservation-related activities, including assessment of development impacts in the Pilbara, survey planning for conservation translocations and fire management.

### Future directions

- Finalise manuscripts for the multispecies population genetics study, the refugia and population expansion study and the multi-species SDM/species richness and landscape connectivity results.
- Disseminate project outcomes and decision-support spatial products to stakeholders in the Pilbara.


## Felixer grooming trap trial: Feral cat control for threatened fauna conservation in the southern forests.

SP 2020-023

A Wayne, M Maxwell, C Ward

### Context

Feral cats are one of the most significant threats to native terrestrial vertebrate species in Australia. The Felixer™ cat grooming trap is a novel method of controlling feral cats that takes advantage of their compulsive grooming

behaviour. The Felixer unit detects the presence of a feral cat and sprays a lethal dose of 1080 toxic gel onto the fur of the feral cat. The feral cat instinctively grooms itself to remove the gel and, in doing so, ingests a lethal dose of the poison. The unit takes a photograph every time the detection beams are crossed, allowing an assessment of the efficacy of the trap in differentiating feral cats from non-target species.

Proper testing of this new technology is essential to validate if the Felixer is an effective and low-risk feral cat management tool and at what scale they are most effective. This project is a research trial to assess the effectiveness of these traps to deliver feral cat control at a meso-spatial scale (around 10,000 ha) for threatened fauna conservation and recovery. The trials are being conducted in high conservation value areas in and around the Tone-Perup Nature Reserve and the Lake Muir-Byenup Ramsar site.

**Aims**

- Determine the safety of the Felixer™ grooming trap for use in the presence of the native fauna in the Upper Warren area.
- Determine whether Felixer™ grooming traps can reduce feral cat densities by at least 60% at a meso-spatial scale (>10,000 ha) in the southern jarrah forests, Western Australia.
- Improve the efficiency and effectiveness of Felixer™ grooming traps by refining the deployment design through adjusting spatio-temporal factors such as density, duration, mobility and location in the landscape.
- Investigate the timing, frequency and spatial scale of Felixer™ trapping required to overcome recruitment from breeding and immigration. Maintain a reduction in cat densities to allow for the recovery of native prey species.

**Progress**

- Safety assessment trials involving 9,521 detections of animals in the southern jarrah forest have demonstrated that the Felixer™ traps pose no risk to the non-target native wildlife.
- Four large field trials resulted in an average target rate for cats of 41% but varied considerably between sites and trials (SD=18.3%, range 17.0 – 73.3%).
- On average between 42% and 58% of the feral cat individuals detected by the Felixers were ultimately targeted by the Felixer during the three main field trials conducted in toxic mode with conservative targeting.
- The one toxic trial in standard targeting mode resulted in 100% of the feral cat individuals detected by the Felixers being targeted.

**Management implications**

- The Felixer units are safe to use in the presence of native fauna present in the southern jarrah forests.
- Early indications are that these units may be able to remove a substantial proportion of individual cats present at a meso-spatial scale, and therefore could be an important and complementary tool to deliver improved conservation outcomes for threatened species vulnerable to cat and fox predation in the jarrah forest.

**Future directions**

- Publication of results in a peer-reviewed paper.

# Ecology, threats and monitoring of the Pilbara Olive Python (*Liasis olivacea barroni*)

SP 2020-006

D Pearson

## Context

The Pilbara olive python (*Liasis olivaceus barroni)* is a threatened species confined to the Pilbara and adjacent northern part of the Gascoyne IBRA region. Little is known about its ecology, habitat preferences and conservation threats. It is an introduced predator consuming a diet of large birds, reptiles and mammals as an adult, including other threatened species such as northern quolls. A number of potential threats confront Pilbara olive pythons, but their relative importance is not understood. They include the loss of important prey items due to exotic predators; habitat loss and modification from mining activities and infrastructure development; and on a local scale, increases in road kills by vehicular traffic due to resource projects and tourism. The project will resolve some of the unknown life history parameters important for conservation of this species and for effective population monitoring. In particular, research will focus on important habitat elements, the reproductive cycle of the species and the predation of juvenile snakes.

## Aims

- Collate and publish existing information on Pilbara olive python biology and management, including the proceedings of a 2013 workshop.
- Document the ecology of Pilbara olive pythons focusing on habitat preferences and life history characteristics (diet, shelter sites, juvenile mortality, reproductive frequency, etc.) likely to be influential in population dynamics and impacted by threats such as wildfire, grazing and mining activities
- Undertake experiments to determine threats to juveniles, the population cohort likely to be most affected by feral animal predation and habitat changes due to fire or grazing.
- Trial and improve existing and novel survey and monitoring techniques to enable more effective assessment and mitigation of potential impacts of resource projects and other land uses on Pilbara olive pythons.

## Progress

- Fieldwork has continued at the Millstream-Chichester National Park study site with further captures of pythons and the implantation of transmitters. A total of 12 pythons have been implanted and radio-tracked to date and have provided valuable information on habitat use and activity patterns.
- A second study site in Karijni National Park has been investigated and searches undertaken for olive pythons. Signs (sloughed skins and suspected faecal pellets) were located but no individuals have been captured to date.
- The first round of experimental trials using model snakes and automatic cameras has been completed and identified a number of potential predators of juvenile pythons, primarily blue-winged kookaburras and sand goannas.
- A paper on the taxonomic position of the Pilbara olive python is nearing completion.
- Input to a review on research directions and management options for the species has been provided.

## Management implications

- Radio-telemetry results indicate that the Millstream pythons have shown a similar intensity of use of elevated rocky areas during cooler months as last year, although the sample size is now considerably larger. This information was conveyed to regional fire staff so that aerial and ground-based burning in these areas is implemented to achieve mosaic patches.
- Extended fieldwork identified two important areas that are heavily utilised by Pilbara olive pythons during the mating/overwinter winter season and need to be considered in planning prescribed burning.

### Future directions

- Ongoing radio-telemetry of Pilbara olive pythons at three sites to document habitat preferences, microhabitat use, diet, reproductive behaviour and sources of mortality in relation to land use.
- Trials to ascertain a suitable method to attach transmitters to the exterior of juvenile pythons.
- Continue trials of various monitoring techniques and their suitability for various geological surfaces and population densities of Pilbara olive pythons.

## Investigation into the decline of Chuditch (*Dasyurus geoffroii*) in the south-west of Western Australia

SP 2019-029

A Wayne, L Gibson, K Ottewell

### Context

Comprehensive information about the distribution, abundance and genetic diversity of the chuditch in Western Australia is lacking. Information to date has largely been captured using Western Shield monitoring, and while this has provided some data for selected locations, the monitoring sites and methods used are designed to capture information on a range of species. Consequently, captures of chuditch are often sparse and monitoring is not comprehensive across its distribution. Analysis of Western Shield data suggests that there has been a significant decline in the relative abundance of chuditch in the period 2013-17, although inconsistent trap effort in some years may have confounded this result. Further analyses suggested that the currently sparse data could not provide reliable population size estimates for the species. This project will undertake targeted surveys in poorly sampled areas to fill information gaps using an approach specific to chuditch. Concurrent DNA sampling will improve an understanding of the genetic structure across the entire species range. The information gained will help to inform decisions both in relation to the effective conservation management of chuditch, as well as sourcing animals for translocations to ensure newly established populations are genetically diverse and representative of the species.

### Aims

- Evaluate survey and monitoring methods to improve future assessments of population change in chuditch.
- Improve knowledge on the distribution of the chuditch by undertaking targeted surveys in poorly sampled areas, and on the margins of its known range.
- Undertake concurrent DNA sampling to improve understanding of the genetic structure across the entire species range, and to identify source populations for translocations.
- Compile and interrogate all data to help identify potential processes influencing population change in chuditch.

### Progress

- Sites were surveyed within the South Coast, Goldfields, Swan, Warren, Wheatbelt and South West regions.
- Captures continued to be significantly higher using chicken instead of universal bait.
- Chuditch were detected at Ravensthorpe, Tone-Perup, Dryandra, Batalling, Avon, Centaur, Catterick, Lake Magenta and Jarrahdale, but not at Cocanarup or Dragon Rocks.
- Lake Magenta and Ravensthorpe yielded the lowest captures (1 and 5 captures in 500 trap nights, respectively), and Dryandra the highest with 58 captures in 400 trap nights.
- Camera traps were established at Jaurdi Station and at Helena and Aurora Ranges to determine if longer term monitoring assists in detecting chuditch.
- Tissue samples for genetic analyses were collected at all sites with chuditch captures except Jarrahdale.
- Tissue samples from 255 individuals were sequenced using samples collected primarily from 2021-2022 monitoring but also included some historical samples from the Goldfields, South Coast regions and those collected from translocated populations. Fitzgerald River National Park population had the greatest genetic differentiation.

- The use of a camera trap approach to monitoring chuditch continues to be investigated.

**Management implications**

- Knowledge on the current distribution of chuditch has been improved, although further surveys are needed to define the eastern extent of the species' range.
- Survey data will facilitate improvements in chuditch population estimates to inform the current conservation status of the species.
- Results of genetic analyses will inform population management, including future translocations to ensure newly established populations are genetically diverse and representative of the species.

**Future directions**

- Further surveys to more clearly define the eastern and northern extent of the species' range.
- Repeat surveys using consistent and chuditch-specific methods to robustly estimate population size at all sites and determine population trends across the state.
- Analyse tissue samples to determine genetic structure.

## Conservation of the night parrot

SP 2017-036

A Burbidge

**Context**

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

**Aims**

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

**Progress**

- Acoustic data continued to be collected from remotely deployed audio recording units.
- A manuscript on establishing effective conservation management actions for the night parrot was published in *Biodiversity and Conservation*.
- Advice on night parrot survey techniques and potential management actions was provided in relation to several proposed resource development projects in areas known or suspected to contain night parrots.
- Guidelines on how to determine and assess the likely presence of night parrots have been revised substantially, and are in the process of being adapted for the DBCA website, primarily to provide information for consultants involved in environmental impact assessments.

### Management implications

- Documentation of known night parrot calls will improve survey and monitoring for the species to facilitate a better understanding of their distribution and conservation status.
- Describing and prioritising conservation management actions will assist in effective recovery of night parrots.
- Survey guidelines will assist environmental consultants in conducting more rigorous surveys, and result in improved knowledge to inform decisions by regulators.

### Future directions

- Continue to investigate development of robust software recognition algorithms.

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

SP 2017-001

D Pearson

### Context

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

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

### Aims

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

### Progress

- All fieldwork, including searching, catching, translocation and radio tracking pythons is complete.
- Assisted Albany veterinarian with the implantation of transmitters in carpet pythons for a study on pythons at the Gilbert's potoroo translocation site.
- Advice provided for the ongoing python project and to the Gilbert's Potoroo recovery team on the impact of carpet pythons on captive and translocated potoroo populations.

### Management implications

- Identification that carpet pythons are significant predators of Gilbert's potoroo means that this needs to be considered when undertaking translocations at Two Peoples Bay and other mainland sites.
- The relocation of large female carpet pythons from the Waychinicup potoroo enclosure and proposed potoroo translocation sites in Two Peoples Bay Nature Reserve would reduce the predation risk.
- The impact of translocation on female pythons may be negative with premature death once removed from known shelter and ambush sites, and that this needs to be considered in any further translocations.

**Future directions**

- Complete papers on the threat that carpet pythons pose to Gilbert's potoroo and survey techniques for pythons.
- Map and analyse data obtained from radio-telemetry to further guide efforts to improve understanding of python ecology on the South Coast of WA.

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

SP 2016-068

A Wayne, M Maxwell, C Ward

**Context**

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

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

**Aims**

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

**Progress**

- Analysis of bait efficiency and effectiveness provides information for recommendations for improvements within an integrated and holistic invasive animals management framework to deliver better biodiversity conservation outcomes. A paper is being finalised following review.
- Analysis of fire effects on introduced predator control shows that compared to the reference sites, there were no significant differences in encounter rates or bait removals by cats or foxes immediately after autumn burns. A paper is in preparation.

**Management implications**

- Controlling feral cats in the southern jarrah forest is challenging and the effectiveness of Eradicat® baiting using existing protocols has been demonstrated.
- The Eradicat® baits can be effective at controlling foxes and are a low risk to threatened species, such that they can complement other methods. Additional introduced predator threat abatement may be needed to conserve and recover many threatened native mammals in the southern jarrah forests.

- Feral cat baiting is most effective when conducted within an integrated and holistic invasive animal management system.

**Future directions**

- Complete analyses and manuscripts for publication, including baiting efficiency in relation to proximity to tracks, bait longevity, non-target bait interactions, and spatial ecology of feral cats.

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

SP 2016-030

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

**Context**

The Dirk Hartog Island National Park Ecological Restoration Project aims to restore the ecological condition of Western Australia's largest island to that seen by Dirk Hartog when he landed on the island in 1616. The establishment of populations of 12 mammal and one bird species on Dirk Hartog Island (DHI) over a 12-year period is a key part of this project. Of these species, one is listed as critically endangered, one as endangered and six as vulnerable under the *Biodiversity Conservation Act 2016*. The other three species are either conservation dependent or near threatened. Their successful re-establishment will contribute to improving the overall conservation status of these species. The translocation of 13 native species to an island 633 square km in area makes it the largest fauna reconstruction project in Australia and one of the largest in the world. For successful re-establishment to occur, sheep, feral goats, and feral cats have been removed. The eradication of feral cats represents the most extensive eradication program achieved globally. Genetic information on source populations is being used to inform founder selection, genetic monitoring of released animals, and ongoing management practices.

**Aims**

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

**Progress**

- Fauna reconstruction on Dirk Hartog Island National Park has passed the halfway mark, with eight species now translocated.
- A supplementation translocation of 44 dibblers from Perth Zoo was undertaken in October 2022.
- Source population monitoring took place for brush-tailed mulgara, western grasswren, Shark Bay bandicoots, Shark Bay mice, dibblers and boodies.
- A total of 85 western grasswrens were translocated from the Shark Bay mainland to Dirk Hartog in spring 2022; subsequent monitoring has revealed persistence at the translocation site.
- A total of 100 brush-tailed mulgara were translocated to DHI from Matuwa Kurrara Kurrara National Park in June 2023; escorted by Wiluna Martu Rangers.
- Ongoing monitoring on the island of Shark Bay bandicoots, Shark Bay mice and rufous hare-wallabies continued to show increases in abundance and extent of occurrence.
- Monitoring of the dibbler and greater stick-nest rat has proved challenging but there was evidence of breeding on the island in both species.

- Monitoring of naturally remaining small vertebrates on DHI indicated native rodents remain abundant; the bull skink (*Liopholis multiscutata*) was recorded on the island for the first time.
- Genetic work on chuditch, brush-tailed mulgara, Shark Bay mouse, boodie and hare-wallaby faecal DNA continued.

**Management implications**

- The successful translocation and establishment of large self-sustaining populations of these eight species on DHI is likely to have beneficial outcomes for their conservation and for the ecosystems they inhabit.
- The development of innovative techniques to enhance translocation and post-release monitoring success will not only be beneficial to this project, but may also improve translocation outcomes at other locations.
- The development of non-invasive approaches to monitor fauna species effectively will provide an effective solution that can be implemented to reduce time in the field and with no requirement for Animal Ethics Committee approval.
- Genomic analysis informs population management strategies and provides a suite of novel, affordable monitoring tools to support the ongoing adaptive management of these populations.

**Future directions**

- One final supplementation translocation of dibblers will be undertaken.
- Monitoring of all translocated species on DHI and source populations will be undertaken.
- Population genomic analyses for above species will be progressed, including new data for desert mouse, and a high-throughput SNP array will be developed for GSNR for faecal DNA monitoring.

## Monitoring of threatened birds on Dirk Hartog Island

SP 2013-021

A Burbidge

**Context**

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

**Aims**

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

**Progress**

- A manuscript on modelled species distribution and population sizes on the island is almost ready for submission for publication.
- Results of the study show that, contrary to expectations, the target species, including the cryptic emu-wren, are all abundant and widespread on the island.

### Management implications

- Clarification of taxonomic relationships indicates that the Bernier Island fieldwren subspecies should be removed from the list of threatened species.
- As all three threatened taxa (fieldwren, emu-wren and fairy-wren) are more abundant and widespread on the island than previously thought, localised management actions will have limited impacts, and monitoring will not need to be undertaken as frequently or as intensively as previously anticipated.

### Future directions

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


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

SP 2013-005

M Cowan

### Context

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

### Aims

- Investigate methodologies for the use of camera traps to examine the temporal and spatial occurrence of native and introduced mammal species in the south-west of Western Australia.
- Investigate and assess methods of data capture and data storage, including emerging automated species recognition technologies.
- Develop analytical tools and methodologies for the interrogation and interpretation of camera trap imagery data.
- Undertake comparative trials on new models of cameras and trapping array designs to assess effectiveness and suitability for monitoring and survey programs.
- Provide analysis of trends and occurrence for critical weight range mammals and introduced predators at landscape scales within targeted reserves.

### Progress

- Presentation on experimental design and field application of camera trap technology in the annual fauna management course.
- Final trial completed using camera traps mounted to trees to monitor red-tailed phascogales in response to Eradicat® ground-baiting.

**Management implications**

- Assessment of variation in detection rates over time for all critical weight range species studied in this project provides essential information on population stability and trends, and the effectiveness of control measures forintroduced predators.
- The camera array at Dryandra forms an essential reference location against which other sites, sampling methodologies and camera trap technology can be assessed.
- Remote camera survey methods (camera type, spatial arrangement, placement, duration, seasonality, use of lures, etc.) should be carefully considered in relation to the targeted species and management questions, to ensure statistically valid inference around species occurrence and spatiotemporal patterns and to provide a sound evidence-based approach to conservation planning and decision making.
- Reconyx camera traps have been among the most effective and dependable commercially available models for departmental requirements and the current model, the HP2X, remains recommended.

**Future directions**

- This project will be complete with finalisation of publications.

## Conservation and management of the bilby in the Pilbara

SP 2012-035

H Moore, L Gibson

**Context**

The bilby (*Macrotis lagotis*) is listed as vulnerable under the *Biodiversity Conservation Act 2016* and the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999*. Increases in threats, including pressure from mining activities across the Pilbara mean that a greater understanding of the distribution, abundance and ecology of the bilby is necessary to ensure appropriate conservation and management measures are implemented. This project aims to increase our knowledge of the bilby in the Pilbara bioregion of Western Australia, and develop 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 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**

- Bilby abundance monitoring near the Warralong community in the Pilbara continued in conjunction with Eradicat® feral cat baiting trials. Ongoing monitoring is required to determine if baiting is effective in reducing feral cat activity, and leads to a positive effect on bilby abundance.
- Preliminary results from an analysis investigating the influence of fire attributes on bilby occurrence in the Pilbara suggest that bilby occupancy decreases with increasing spatial extent of recently burnt habitat in the surrounding landscape, and increases with pyrodiversity (diversity of fire ages).
- A complementary project on the Dampier Peninsula in the Kimberley showed that bilby occupancy increased with increasing spatial extent of surrounding long unburnt habitat (greater than 3 years old), while feral cat occupancy declined. Similarly, frequent fires tended to deter bilbies but not feral cats.
- A review of the bilby research program was completed, with future research directions and management actions identfied.

### Management implications

- Recent findings further highlight the importance of appropriately managing fire to benefit bilby populations.
- Improved understanding of the effectiveness of threat mitigation will help inform ongoing conservation management of the bilby across its range.
- Ongoing surveys for bilbies across the Pilbara will improve our understanding of their conservation status in this region and assist assessments of development proposals.

### Future directions

- Continue the monitoring at Warralong to assess the effectiveness of threat management.
- Continue investigating the role of fire in improving bilby habitat across their current range, as well as how fire may interact with other threats (predation).
- Develop a strategy to commence implementation of the research priorities identified in the review.

## Genetic assessment for conservation of rare and threatened fauna

SP 2012-034

K Ottewell, M Byrne, R Sun, L Umbrello, B Huntley, M Millar

### Context

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

### Aims

- Assess the genetic diversity and genetic structure of target species.
- Use genetic approaches to assist in resolving taxonomic boundaries of target species.
- Undertake genetic monitoring of translocated and natural populations of target species.
- Use novel genetic technologies to assist and/or inform conservation management of target species.

### Progress

- A manuscript on population genomic analysis of island and mainland golden bandicoots has been submitted.
- Population genomic analysis of black-flanked rock wallaby has been progressed and a manuscript on the success of the Kalbarri National Park translocation has been published.
- Bilby faecal DNA monitoring is continuing with further refinement to lab methods to screen samples using a qPCR assay prior to SNP genotyping. A draft manuscript is in preparation.
- Refinements to the ScatMatch R package to incorporate analysis of microsatellite data for non-invasive genetic monitoring are ongoing.
- A paper describing non-invasive genetic monitoring of mala at Matuwa has been published in *Wildlife Research*.
- Statistical analyses of wild, translocated and historical populations of Gilbert's potoroo has been undertaken. Further refinement of a SNP panel for genetic monitoring is underway.
- Microsatellite analysis of hairy marron samples to identify putative hybrids has been completed and a report provided.

### Management implications

- Genetic analysis showed mixing divergent populations of black-flanked rock wallaby in translocations increases genetic diversity. Interbreeding of wheatbelt and indigenous Kalbarri rock wallabies suggests population augmentation can be a successful strategy.
- High-throughput SNP genotyping methods have enabled rapid, cost-effective screening of non-invasive DNA samples of bilbies and mala to assist monitoring of these elusive species.
- Genetic analysis of Gilbert's potoroo populations has indicated that Bald Island, in particular, retains a high proportion of the genetic diversity previously extant at Two People's Bay. Genetic results have underpinned a recent translocation proposal to reinforce the Two People's Bay population.
- Genetic analysis of hairy marron samples indicated that the captive breeding population consists of pure hairy marron individuals with no contamination from smooth marron.

### Future directions

- Finalise submission of golden bandicoot manuscript. Contribute to collaborative manuscript on *Isoodon* taxonomy.
- Finalise submission of Kalbarri black-flanked rock wallaby manuscript and complete genomic analyses.
- Contribute to collaborative manuscript on bilby genetic resources, outlining bilby SNP array development and analysis.
- Provide bilby SNP genotyping as required for genetic monitoring projects.
- Complete population genetic analyses for Gilbert's potoroo and develop SNP array for genetic monitoring.
- Provide further refinements to the ScatMatch R package to incorporate microsatellite data.

## Barrow Island threatened and priority fauna species translocation program

SP 2012-025

L Gibson, A Burbidge, C Sims, J Angus, S Garretson

### Context

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

### Aims

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

### Progress

- Boodies and golden bandicoots translocated from Barrow Island to a fenced enclosure at Matuwa Kurrara Kurrara National Park (MKKNP) continued to be monitored.
- Introduced predator control continued at MKKNP and Cape Range National Park.
- Monitoring of mammals and birds translocated from Barrow Island to the Montebello Island group was undertaken with evidence of widespread dispersal on the islands.

### Management implications

- Arid zone rangelands fauna reconstruction and conservation techniques developed by this project will have broad State and national application.
- This project has contributed to an improvement in the conservation status of several threatened fauna taxa.

### Future directions

- Continue the monitoring of translocated populations at Matuwa Kurrara Kurrara National Park.
- Continue monitoring the effectiveness of integrated fox and feral cat control at Cape Range.

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

SP 2012-024

C Lohr, L Gibson

### Context

Operation Rangelands Restoration commenced in 2000 with the acquisition of Lorna Glen (Matuwa) and Earaheedy (Kurrara Kurrara) ex-pastoral leases by the WA Government, that were made a National Park in 2023. We are working in collaboration with the traditional owners, Tarlka Matuwa Piarku Aboriginal Corporation, who were granted exclusive native title over the area in 2014, to restore ecosystem function and biodiversity in the rangelands. Matuwa once supported many mammal species, that have suffered large declines. This project seeks to reintroduce 11 arid zone mammal species following the successful suppression of feral cats and foxes. Mammal reconstruction will also contribute to the restoration of rangeland ecosystems through re-establishment of ecosystem services such as digging, grazing/browsing of vegetation and seed dispersal. The first mammal reintroductions commenced in August 2007 with the release of bilby (*Macrotis lagotis*) and brushtail possums (*Trichosurus vulpecula*). Between 2010-2012, mala (*Lagorchestes hirsutus*), Shark Bay mice (*Pseudomys fieldi*), boodies (*Bettongia lesueur*) and golden bandicoots (*Isoodon auratus*) were translocated into a 1100 hectare introduced predator-free fenced enclosure. The enclosure is intended to provide species with an opportunity to acclimatise to the desert environment. The ultimate goal is to release animals outside the enclosure and establish free-ranging, self sustaining populations of these species.

### Aims

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

### Progress

- Introduced predator control via aerial baiting with Eradicat® continued and the track activity index suggested continued to successful suppression of feral cat numbers.
- A manuscript discussing the efficacy of various lures for camera-traps used to monitor feral cats is being prepared.
- Assessment of the susceptibility of golden bandicoots to the Eradicat bait was completed with data suggesting the bandicoots are at minimal risk from the baiting. A manuscript is being prepared.
- A manuscript describing the impact of fenced reserves on mulgara has been submitted to *Australian Mammalogy*.
- A manuscript describing the genomic diversity in golden bandicoots has been submitted to *Heredity*.
- Monitoring of boodies, golden bandicoots and mala inside the enclosure continued.
- Improved trapping protocols for mulgara and golden bandicoots were developed by altering bait type and shelter provisions.

- 100 mulgara were translocated from Matuwa to Dirk Hartog Island, WA.
- A new round of surveys measuring mulgara and bilby abundance on Matuwa was completed.

**Management implications**

- Annual landscape scale feral cat baiting plus additional control techniques are required to successfully re-establish threatened vertebrate fauna in the rangelands.
- Long-term feral cat control confers benefits to many mid-sized and small fauna species.
- Urine lures improve the quality of data captured by camera-traps when assessing feral cat abundance.
- Increased involvement of traditional owner rangers with fauna monitoring has assisted collaborative management.
- Potential over-abundance of boodies in the enclosure needs to be carefully managed.
- Matuwa has become a source site for boodies, golden bandicoot, and mulgara translocations.

**Future directions**

- Provide training opportunities for Wiluna Rangers and community members, and participate in two-way science with TMPAC and Wiluna Rangers.
- Monitor reintroduced species, introduced predators and other native arid zone species, such as malleefowl.
- Initiate co-design of boodie release into the unfenced landscape at Matuwa.
- Complete publications on the ecology of boodies, lures for camera-traps, and the impact of baiting on golden bandicoots.

## Conservation of south coast threatened birds

SP 2012-022

A Burbidge, G McGrath

**Context**

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

**Aims**

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

**Progress**

- In collaboration with South Coast Region, a further five western ground parrots were translocated from Cape Arid National Park to a site east of Albany, amounting to 19 individuals in total.

- Innovative monitoring approaches, including Autonomous Recording Units (ARUs) and Unmanned Aerial Vehicles (drones), were used to measure translocation success.
- Contributed to a book chapter, published by CSIRO, and a scientific paper in *Biological Conservation*, concerning impacts and management of the mega-fires in 2019-20.
- Commenced a project to link threatened species occurrence data, food resources, vegetation structure and composition, fire age and remotely sensed data, to develop predictive tools for fire management.

**Management implications**

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

**Future directions**

- Analyse survey data for ground parrots, scrub-birds, bristlebirds, and bitterns.
- Examine occupancy of ground parrots in relation to fire.
- Continue to monitor key populations of Australasian bittern and their habitat

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

SP 2011-005

H Moore, L Gibson

**Context**

The northern quoll (*Dasyurus hallucatus*) is listed as an endangered species under the *Biodiversity Conservation Act, 2016*. Funding from mining offset conditions is being used to gain a better understanding of quoll distribution, ecology, demographics and management requirements in the Pilbara. The two major components of the project are monitoring and ecological research. 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 barriers restricting dispersal opportunities and genetic flow.

**Aims**

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

**Progress**

- A review of the northern quoll research program, published in *Australian Mammalogy*, found that the program has substantially improved our knowledge of Pilbara northern quolls, particularly in relation to effective survey and monitoring techniques, the influence of habitat quantity, configuration, and composition on occupancy, movement ecology, population dynamics and structure, and the threat posed by introduced predators.

- An analysis of northern quoll fine-scale habitat, published in *Australian Mammalogy*, found that quolls selected habitats that were topographically rugged, and characterised by a higher percentage cover of rocky habitat and riverbed, and a lower percentage cover of spinifex sandplain.
- An analysis comparing the efficiency of new (camera traps) and conventional (live trapping) survey methods in terms of cost and statistical power in tracking occupancy declines in northern quolls, published in *Conservation Science and Practice*, indicated that camera traps can detect declines of 30%, 50% and 80% at a reduced cost when compared to live trap designs, without compromising statistical power.
- A complementary paper published in *Conservation Science and Practice*, discussed the implementation of improved quoll monitoring methods and the benefits associated with involving local stakeholders.
- An analysis exploring the relationship between northern quoll habitat suitability and mean population fitness, published in *Wildlife Research,* indicated that mean population fitness increased with increasing habitat suitability, increasing topographic ruggedness, annual rainfall, rainfall variability, and decreasing distance to water.
- Northern quolls were detected on the Burrup Peninsula for the first time in almost 10 years, as part of collaborative monitoring efforts with the Murujuga Rangers.

**Management implications**

- Advancements in surveying and monitoring techniques, such as the use of camera traps, offer a more cost-effective and statistically powerful method for tracking the population dynamics of northern quolls. Monitoring programs that effectively track population trends allow for timely responses to any significant declines or changes.
- Identification of the importance of topographically rugged habitat, as well as linear features, such as creek beds for northern quolls, informs management strategies that protect these preferred habitats and provide benefits to the species.
- Engaging local stakeholders strengthens DBCA's capacity to monitor northern quolls effectively at scale in the Pilbara, and increased the capacity of Indigenous ranger groups to undertake their own monitoring of other culturally significant fauna.

**Future directions**

- Further refine the northern quoll regional monitoring program.
- Improve understanding of how interacting threats such as introduced predators, fire, and herbivore grazing influence northern quoll populations in the Pilbara.
- Further investigation of how other threats such as mining associated activities and the impending cane toad invasion can be best mitigated.

## Impact of cane toads on biodiversity in the Kimberley

SP 2006-004

D Pearson

**Context**

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

### Aims

- Test of taste aversion baits and the use of 'teacher toads' (metamorphs too small to be lethal) to induce an effective conditioned taste aversion (CTA) response by native species threatened by toads.
- Develop operational techniques to roll out taste aversion training across Kimberley landscapes.
- Monitor populations of susceptible species behind the toad front, including those where taste aversion training took place and at control sites.
- Investigate where and how toads survive in seasonally dry habitats to better understand their colonisation of islands and their potential to spread into the Pilbara region.

### Progress

- Fieldwork is complete and current effort is focused on analysing and writing up studies on the impact of the arrival of cane toads on Adolphus Island and the taste aversion bait trials on Theda Station and at Mt Hart.
- Advice has been provided to the Cane Toad Program and associates.

### Management implications

- Trials of DBCA conditioned taste aversion baits resulted in equivocal results, with small numbers of quolls persisting on both control and treatment sites after the arrival of cane toads. The differences are being carefully teased out using video and camera footage to understand how quolls interact with the baits.
- CTA baits were found to be effective at inducing quoll avoidance of the baits and toad legs. Results from this work and research by others suggests that quolls do not remember their taste aversion experience for a long period (weeks). Therefore, it is important that aerial drops of CTA baits occur both early, and at other times in the wet season, so that quolls have likely encountered a CTA bait a short time before they meet their first toad.

### Future directions

- Data analysis and publication of CTA trials on wild and captive quoll populations with recommendations on how baits could be employed to protect mainland and island northern quoll populations.
- Publication of information on the impact of cane toads on various other taxa.

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

SP 2003-005

D Algar, N Hamilton, M Onus

### Context

The effective control of feral cats is one of the most important native fauna conservation issues in Australia. Development of an effective landscape-scale baiting technique, and the incorporation of a suitable toxin for feral cats, is cited as a high priority in the various iterations of the national *Threat abatement plan for predation of feral cats*, as it is most likely to yield a practical, effective, and cost-efficient 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 baiting strategies to provide long-term and sustained effective control.
- Assess the potential impact of baiting programs on non-target species and devise methods to reduce potential risks where possible.
- Provide a technique for the reliable estimation of cat abundance.

- Refine the feral cat trapping technique to effectively collect information on population parameters relevant to control strategies, while minimising risk to non-target species. Assess the utility of trapping as a follow-up measure post-baiting where eradication of cats is required or to provide additional control effort.

**Progress**

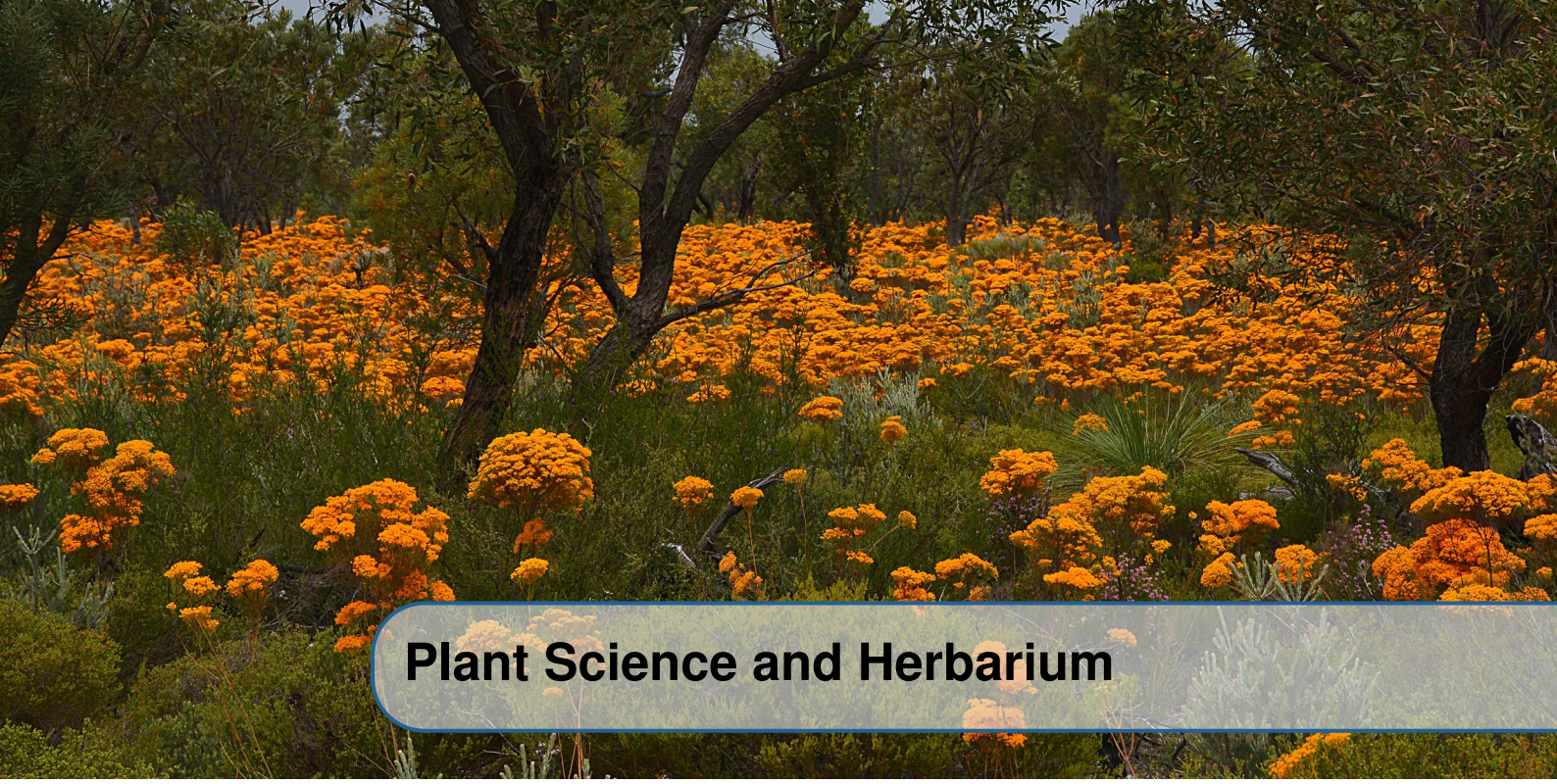
- Field trials commenced to examine coating of baits with an attractant to improve palatability. These trials are showing considerable promise and will continue, across four biomes, in spring and autumn for the next two years.
- Trials to monitor cat activity and movement patterns, using satellite radio-collars, are underway at several sites (Avon Valley/Walyunga National Parks and Francois Peron National Park) to inform targeted bait delivery during future landscape-scale aerial baiting campaigns. This information will be used to increase likely bait encounter rate when cats are hungry and result in improved baiting efficacy.
- A number of novel lures (including dispensing units) are being tested for their utility as attractants to monitor cat abundance and enable reliable and repeatable measurement of control efficacy. This research includes collaborative work with Murdoch University on an 'Artificial Intelligence' remote camera system.

**Management implications**

- Effective landscape-scale baiting methods, based on cat activity and movement patterns, across climatic regions will ultimately provide efficient feral cat control at strategic locations across mainland Western Australia and lead to significant conservation benefits.
- Development of effective statewide monitoring and trapping techniques that minimise risk to non-target species, will complement the control toolkit and improve ability to collect data relevant to management options.
- Successful eradication of feral cats and maintenance of cat-free status on all islands off the Western Australian mainland allows persistence of the native fauna on these islands and enables effective reintroductions of mammals where appropriate, and restoration of habitat and ecosystem processes.

**Future directions**

- Further refine the bait medium and manufacturing methodology to improve both bait palatability and quality.
- Further analyse the baiting operation and refine the methodology where necessary to optimise baiting efficacy.
- Continue investigation of attractants that could prove to be a suitable lure for the reliable and accurate monitoring of feral cat populations.



# Plant Science and Herbarium

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

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

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

SP 2018-041

M Byrne

### Context

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

### Aims

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

### Progress

- Genomic analysis of 870 samples from 37 populations from Queensland, 35 populations from the Northern Territory and 14 populations from Western Australia that represent the introduced range in Australia, showed low diversity and confirm the expansion of one of the introduced lineages from Ecuador across northern Australia from the location of introduction in Queensland.
- Further analysis of samples collected to align with ecological analysis of populations in Western Australia show very low diversity.
- A manuscript on genetic diversity across the distribution is being finalised.

### Management implications

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

### Future directions

- Finalise manuscript on the population genetic analysis of collections from the invaded range in Australia.
- Investigate options for whole sequence analysis to determine adaptation, considering the low diversity that has been found in populations in Australia.

## Interactive key and taxonomic studies of Myrtaceae tribe Chamelaucieae

SP 2013-052

J Wege, C Ely

### Context

Myrtaceae tribe Chamelaucieae (>800 species) is a diverse and horticulturally important element of the Australian flora with a significant number of conservation-listed taxa and many undescribed species. Existing taxonomic knowledge gaps not only impede accurate species identification by stakeholders, but assessment of conservation status, research (in fields other than taxonomy), and commercial utilisation.

### Aims

- Publish a series of taxonomic papers describing new species and genera.
- Build a *Flora of Australia* treatment of tribe Chamelaucieae.
- Continually update identification guides.

### Progress

- Two research papers resolving taxonomic issues in *Hypocalymma* were published in *Nuytsia* along with nomenclatural articles on *Astartea* and *Corynanthera*.

- Taxonomic treatments of *Aluta*, *Anticoryne*, *Astartea*, *Astus*, *Austrobaeckea*, *Balaustion*, *Cheyniana*, *Enekbatus*, *Ericomyrtus*, *Euryomyrtus*, *Oxymyrrhine*, *Rinzia* and *Seorsus* were published online in *Flora of Australia*. The associated identification keys were simultaneously updated on *KeyBase*.
- Targeted field work was conducted to obtain specimens and photographs of select species.

**Management implications**

- An improved understanding of the species diversity in tribe Chamelaucieae and the mobilisation of species descriptions, validated herbarium specimen data and identification guides will facilitate conservation efforts.

**Future directions**

- Continue data mobilisation, with a focus on Flora treatments.

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

SP 2012-006

R Davis

**Context**

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

**Aims**

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

**Progress**

- Published a description of *Acacia armigera* (Fabaceae), a new, geographically restricted wattle from the Coolgardie bioregion of Western Australia, in *Nuytsia*.
- Published a description of *Darwinia chantiae* (Myrtaceae), a new species from Western Australia, in *Australian Journal of Taxonomy*.
- Completed *Common Wildflowers of the South-West Forest & Common Trees of the South-West Forests,* in the Bush Books series.

**Management implications**

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

**Future directions**

- Preparation of further papers describing new taxa in *Ptilotus, Gomphrena*, *Swainsona* and other genera (*Acacia* and *Eremophila*).
- Further field studies to assist in the resolution of problematic groups within *Ptilotus*.
- Progress interactive keys to *Ptilotus, Gomphrena* and *Swainsona*.

## The Western Australian Plant Census and Australian Plant Census

CF 2011-111

C Parker, J Percy-Bower, T Macfarlane, S James

**Context**

The Western Australian Plant Census (a component of WACensus and Nomos) is the authoritative database of the flora (vascular and non vascular plants, algae, fungi and slime moulds) found in Western Australia, including synonyms created by taxonomic research and concept changes. It is continually updated to reflect changes in our knowledge of the flora. The census constitutes the fundamental master list for many departmental processes and data sets, including the threatened and priority flora database maintained by the Species and Communities Program, the Herbarium's specimen database (WAHerb), Max (the departmental software for information based on taxonomic names), *Florabase* and *Dandjoo* (Biodiversity Information Office).

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

**Aims**

- Maintain an accurate and timely listing of all plants, algae, fungi and slime moulds in Western Australia, including current names and synonyms, and harmonize this with the national taxonomic consensus.
- Provide taxonomic advice and updates for Nomos.

**Progress**

- 647 plant names (614 formally published and 33 informal names) were added to the WACensus during 2022-23. The inclusion of crytopgams (particularly fungi, lichens and freshwater algae) in WACensus is currently a focus.
- A total of 1374 data updates were made to the WACensus.
- Plant groups for which significant name changes were made include *Styphelia* (24 species; 400 collection items), *Euploca* (50 species; 950 collection items), *Pigea* (10 species; 990 collection items) and *Eucalyptus* (20 species; 1500 collection items). A number of new taxa were formally published in *Grevillea* (12 species; 300 collection items). Numerous phrase-named taxa in the genus *Baeckea* were formally published under *Austrobaeckea* and *Balaustion* (30 species; 500 collection items), and a significant revision of Phyllanthaceae resulted in the transfer of *Phyllanthus* species to other genera (20 species; 1200 collection items).
- WACensus updates were regularly distributed to 170 registered Max users.
- More than 1700 archived census forms, including descriptions of phrase name taxa, were scanned by volunteers and are now electronically available for internal use.

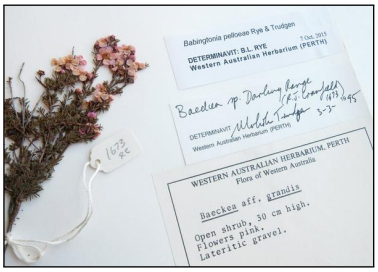
- Herbarium staff contributed to discussions on Australian taxonomy and nomenclature resulting in the annual publication of a national consensus known as the APC for the National Species List. The State's contribution to maintenance of this national cooperative database continued with the addition of 347 new vascular plant names and the creation of 2112 new instances (data on synonymy, authors and publications).
- The Western Australian Plant Census is an integral part of the Biodiversity Information Office platform, Dandjoo and taxonomic names system, Nomos. The Herbarium team has assisted with more than 400 queries relating to taxonomic updates in the past year.

**Management implications**

- WACensus provides users with a single, authoritative official list of the flora of Western Australia, with their currently accepted classification, scientific name, correct spelling and authority. Delivery of this information is through the *Florabase* website, Max, and other linked databases or websites.
- Users of plant names can 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 names through WACensus.
- WACensus feeds Western Australian information to national biodiversity systems such as the Atlas of Living Australia, Australasian Virtual Herbarium, the Australian Plant Census (National Species List), and the e-flora of Australia. The national list contributes to international names databases such as the Global Biodiversity Information Facility and Encyclopedia of Life.

**Future directions**

- Development of a new, more efficient online database forum for APC.
- Continue to provide a comprehensive and up to date State and national census across all plant, algae and fungal groups.
- Continue to ensure the collections of the Western Australian Herbarium remain taxonomically correct for biodiversity and conservation research.




## The Western Australian Herbarium specimen database

CF 2011-110

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

**Context**

The Western Australian Herbarium collection management system (WAHerb) allows staff at the Herbarium to manage, maintain and share the Herbarium's botanical specimen metadata. It also allows the transactional management of the collections (loans, exchange and sampling). It provides core data on the distribution, ecology and morphology of taxa for the department and the community, through *Florabase* and other biodiversity data aggregators. Data from the collections database is provided to researchers, consultants and community members on request, and to the Australasian Virtual Herbarium (AVH), Atlas of Living Australia (ALA), Global Biodiversity Information Facility (GBIF), and Dandjoo (Biodiversity Information Office) on a regular basis.

**Aims**

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

**Progress**

- The Western Australian Herbarium added 10,015 specimen records in 2022-23.
- The metadata of more than 43,800 specimen records were edited ensuring the hebarium collection and data are scientifically valid, accurate, up-to-date, and the taxonomy aligned with the department's conservation designations.
- Customised specimen data reports (species lists and label data) were provided to departmental officers, researchers and the public regularly upon request.
- An instance of the Integrated Publishing Toolkit, established in 2022, has enabled streamlined delivery of a Darwin Core Archive of the Herbarium data to biodiversity data aggregators on a weekly basis.
- Through the AVH and ALA, 73 million herbarium data records were downloaded in 11,600 download events. The Western Australian Herbarium dataset is also available via the Global Biodiversity Information Facility (GBIF - 981 million records in 28,200 download events) and through Dandjoo.
- Data cleaning and migration activities continue towards planned migration to a new collection management system (Specify).
- Extended specimen data, including publication history and genetic data, are being gathered in preparation for migration to the new collection management system.
- More than 3200 high resolution images of Herbarium specimens were captured and shared with departmental staff and industry consultants and a further 72 high resolution images of type specimens were captured and shared with the online Global Plants Initiative. Specimen imaging is focused on the 3900 threatened and priority taxa, an initiative to digitally transform the Herbarium collections.

**Management implications**

- WAHerb enables the management of the State's botanical collections assets. The migration to Specify will further increase productivity and provide management tools not previously available.
- WAHerb represents the most comprehensive vouchered specimen database for Western Australian plants available and provides a source of information that consultants, land managers, and policy makers can use for updates on conservation status, plant identification, clarification of plants in an area and identification of knowledge gaps. This ensures that all research and management activities are informed by up to date and valid botanical species names.
- The curated herbarium collections data is a much utilised digital resource for systematic and taxonomic research, collections management, environmental assessment, ecological and other scientific research, restoration and remediation projects, biosecurity management and planning, educational uses and citizen science.

**Future directions**

- Continue timely addition, editing and validation of specimen records to maintain currency and connectivity between the Herbarium collection, the Western Australian Plant Census and departmental and external biodiversity data providers, including Florabase, Dandjoo, AVH, ALA, and GBIF.
- Complete migration of the collection management system to Specify.
- Develop a mass specimen imaging volunteer program to accelerate the capture of specimen images for online access.
- Collaborate with DBCA library to scan field notebooks to enhance digital biodiversity data associated with specimens.
- Collaborate with the Aboriginal Engagement, Planning and Lands Branch on the management of culturally sensitive data.


## Herbarium collections management

CF 2011-105

S James, C Parker, J Huisman, J Percy-Bower, S Coffey, E Wood-Ward, M Hislop, R Davis, S Sinha, R Gugiatti, C Ely

### Context

The Western Australian Herbarium houses the State's botanical physical and digital collections, the core resource for knowledge of the State's plants, algae, fungi, and slime moulds. The collection is growing constantly and consistently through accessions of specimens from internal and external sources. New taxa are documented as voucher specimens and digital records. The collections are maintained to the highest standard utilising international natural science collections and archival best practice, and provide the department and the community with the fundamental resource that provides knowledge of the diversity, temporal and spatial distribution, and abundance of the flora throughout Western Australia.

### Aims

- Document and audit the diversity of Western Australia's plants, algae, fungi, and slime moulds.
- Maintain, in perpetuity, a comprehensive and representative research and reference collection of specimens of all taxa in groups occurring in, and adjacent to, Western Australia.
- Contribute to, support and service the biodiversity research, conservation and decision-making activities of the department and stakeholders.
- Contribute to, support and service taxonomic and other research by the local, national and international scientific community.
- Provide digital resources enabling open access to the botanical collections.

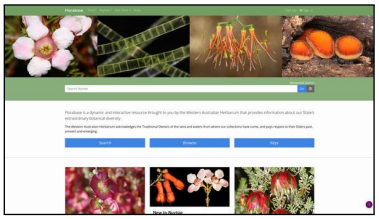
### Progress

- The Western Australian Herbarium added 10,015 specimens to collections, including 933 specimens of priority taxa and 181 specimens of threatened taxa, increasing the size of the collection to 843,021 catalogued items representing more than 18,789 taxa.
- The Western Australia Herbarium shared specimens with nine national and seven international institutions, and shipped 260 specimens in six loans for scientific research. A total of 3710 exchange specimens were sent to collaborating institutions, and 16 requests for 270 tissue samples from herbarium specimens were processed for molecular and other scientific analyses.
- Major activities within the collections included substantial and targeted reduction in unprocessed specimens (all collections pre-2014 now processed), incorporation of specimens returned to the Western Australian Herbarium from Manjimup (390 specimens), processing and incorporation of Herbarium Lowerianum (700 specimens), Robert Brown Iter Australiense historical specimens (165), Bush Blitz specimens (460 specimens), and completion of the incorporation of specimens received from the South West Regional Herbarium (1920 specimens).
- Specimens and data were cited in more than 130 publications; the collection and associated data have been cited 3025 times since the early 1900s.
- A collection of Type specimen photographs continues to be developed (currently >1375 items), increasing the space within the Types Vault and improving care of the physical (true) Type specimens.
- With the assistance of volunteers, 9400 specimens were mounted.
- Volunteer participation continues to be a significant and invaluable resource, totaling 3725 hours - equivalent to approximately 2.4 full time employees. The Herbarium was assisted by 30 regular volunteers and 14 Research Associates.
- The Reference Herbarium was accessed 2450 times by visitors, volunteers and industry consultants for plant identifications and other scientific purposes.
- The Research Collection was accessed 1600 times by visitors for the study and identification of taxa.
- The Herbarium Identification Program provided identifications to a range of clients, including departmental staff, other government agencies, environmental consultancies, regional herbaria and the public. More

than 2309 specimen identifications in 48 transactions, along with more than 50 image-based identifications, were undertaken for external clients.
- Educational programs consisted of 12 herbarium tours and monthly induction sessions for departmental staff, tertiary institutions, environmental consultancies, community groups and the media (approximately 300 participants). A display in the Atrium is regularly updated to highlight the work of the Western Australian Herbarium. The Herbarium also trained two UWA Work Integrated Learning interns, one UWA McCusker intern, and one Notre Dame intern.
- The Western Australian Herbarium facebook page, with more than 7300 followers, shares a monthly 'Plant of the Month' and other interesting botanical announcements.
- The herbarium currently has an estimated 41,000 uncatalogued specimens dating back to 2014.

**Management implications**
- Maintenance and curation of the Western Australian Herbarium botanical collections provides an authoritative inventory of the biodiversity of Western Australia, which underpins flora conservation and State, national, and international biodiversity research programs.
- The collections are drawn upon constantly by DBCA staff, consultants and policy makers to validate specimen records from biological surveys, environmental impact assessments, assess the conservation status of native taxa, and document the introduction of invasive species.
- The curated collections data is a much utilised digital resource for systematic and taxonomic research, collections management, environmental assessment, ecological and other scientific research, restoration and remediation projects, biosecurity management and planning, educational uses and citizen science.

**Future directions**
- Develop curation workflows and volunteer programs that enable the imaging of physical collections and field notes for online delivery and sharing.
- Continue to significantly reduce and make available the currently unprocessed and uncatalogued specimen items in storage.
- Support implementation of a new collections management system (Specify) that will increase scope for the extended specimen initiative and improved and efficient management of the specimen collections.
- Scope gap analysis for collections, and participate in Bush Blitz expeditions.



## 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 State's central warehouse for botanical taxonomic information. Florabase draws from three core databases for names (WACensus), specimens (WAHerb) and images (Imagebank). Actively managing the currency, authority, data quality, and linkages between these datasets is an important task, both for maintaining Florabase and contributing to State, national and global plant information resources such as Dandjoo, the Atlas of Living Australia (ALA) and the Global Biodiversity Information Facility (GBIF). WAHerb is the Herbarium's specimen database and is the sole source of specimen data used by Florabase. Imagebank is the Herbarium's image collection.

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

### Progress

- Released new maintenance versions of Florabase, Publishing System and Imagebank.
- Migrated the *Nuytsia* Journal database out of its outdated database environment, commenced attributing Digital Object Identifiers (DOIs) to *Nuytsia* journal articles via CrossRef, and published a new version of Florabase to display and use DOIs.
- Provided data and system analysis, project planning, initial code implementation and other activities to migrate WAHerb into Specify.

### Management implications

- Florabase is an essential data library that allows the community and department staff to retrieve the most recent information on the name, features, status and distribution of the 17,738 currently recognised native and naturalised Western Australian vascular plant, alga, fungi, lichen, moss and slime mould taxa. Species conservation and land management efforts across the State are made more effective by access to this authoritative information.
- Migration of WAHerb into the Specify Collection Management Platform will provide enhanced management of the authoritative source of data for any application relying on Western Australian plant specimen data.
- Adoption of new technological developments in biodiversity informatics systems, ensures that Western Australian data is made available to the broadest possible audience, and that data from other sources can be integrated with local data for more effective delivery of research outputs and outcomes.

### Future directions

- Complete migration of data into Nomos, Data Catalogue and Specify.
- Continue the development of up-to-date, integrated and accessible data catalogues and databases.
- Continue to ensure data is effectively captured, curated and accessible to support conservation management and decision-making.
- Upgrade, merge or decommission applications as appropriate.

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

SP 2011-015

M Hislop

### Context

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

### Aims

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

**Progress**

- Three rare new species of *Conostephium, Dielsiodoxa* and *Styphelia* published in *Nuytsia*.
- Thirteen new species of *Styphelia,* nine with conservation coding, published in *Nuytsia*.
- A new priority-listed species of *Stenanthera* was published in *Swainsona*.
- A new priority-listed species of *Acrotriche* was published in *Nuytsia*.
- A paper describing another three new species of *Styphelia* and an updated description of a long-established species were submitted to *Nuytsia*.

**Management implications**

- The epacrids, of which *Styphelia* (in the newly expanded sense) and *Leucopogon* are the largest genera, have a major centre of diversity in south-west Western Australia. An authoritative source of current information is fundamental to appropriately manage the conservation-listed 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.*

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

SP 2011-001

T Macfarlane

**Context**

Successful conservation of flora requires that conservation units equate to properly defined, described and named taxa. There are numerous known and suspected unnamed taxa in the grass, legume and 'lily' (now Asparagaceae and Hemerocallidaceae) families, and 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 *Thysanotus*, *Wurmbea*, *Caesia*, *Lomandra*, *Amphipogon* and *Trithuria*.

**Aims**

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

**Progress**

- A paper on the conservation genetics project to resolve the *Wurmbea dioica* species complex is in preparation.
- Further new species of the *Thysanotus patersonii* group of twiners were distinguished through field research and two other suspected new species were confirmed and descriptions drafted. A paper on multi-ovulate species is in revision.
- Molecular phylogeny of Lomandra was completed and a paper accepted by *Botanical Journal of the Linnean Society*.
- Molecular analyses of *Caesia* phylogeny were undertaken with a paper in preparation, addressing the generic classification of current *Caesia* and *Corynotheca* species.

- A paper resolving several phrase names of *Alyogyne* (Malvaceae), a genus with showy, often cultivated species, under new or existing names was submitted to *Swainsona*.
- An international PAFTOL molecular phylogenetic study of the grass family (Poaceae), based at Kew, UK, has progressed to paper writing.
- Contributed taxonomic, identification and scientific name advice on priority conservation species and surveyed poorly known species.

**Management implications**

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

**Future directions**

- Finalise papers describing new species of *Wurmbea*, *Thysanotus, Amphipogon.*
- Conduct field searches for species or populations of relevant families that are insufficiently known.
- Contribute articles about research results on *Thysanotus* and *Wurmbea* for general audiences in *Landscope.*
- Continue to revise Thysanotus and Wurmbea and investigate putatively new species of various genera.

## 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 Australia's most abundant and diversified genera. 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. The most significant issue at this point is the lack of an overarching flora treatment for the family Stylidiaceae, which hinders survey and accurate identification by conservation personnel, botanical consultants and other stakeholders.

**Aims**

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

**Progress**

- Taxonomic data continues to be generated and consolidated for *Flora of Australia*, with several associated manuscripts being prepared in parallel.
- Several new species from Western Australia, the Northern Territory and Queensland were resolved, and flora profiles for a majority of Territorian species were drafted.
- 881 Stylidiaceae specimens at the Western Australian Herbarium were annotated to correct or confirm their identity, improving our understanding of the distribution and rarity of the State's species. 990 photographic

records have also been identified on Inaturalist, some of which represent new populations of poorly known species.
- Targeted field work in south-western Australia was conducted to resolve outstanding taxonomic issues, collect voucher material, and capture photographs for identification guides.
- A paper on phylogenetic relationships in Stylidiaceae has been advanced.

**Management implications**
- Herbarium-based taxonomic research and targeted field work continue to improve our understanding of the distribution, habitat requirements and conservation status of Australia's triggerplant flora.
- A phylogenomic framework will provide an evolutionary context for conservation management.

**Future directions**
- Continue writing species profiles for the *Flora of Australia* and associated research papers, visiting select Australian herbaria as required.
- Progress identification guides and complete phylogenetic papers.

## 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 biodiversity conservation programs. It includes floristic studies of the marine plants of several existing and proposed marine parks and areas of commercial interest, to provide baseline information that will enable a more comprehensive assessment of the Western Australian marine biodiversity. These include Shoalwater, Marmion, Ningaloo, Dampier Archipelago, Barrow Island, Montebello Islands, Rowley Shoals, Scott Reef and the Maret Islands.

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

**Progress**
- A revised and expanded version of the book *Marine Plants of Australia* was published by UWA Publishing. It incudes descriptions and illustrations of over 640 species of marine algae and seagrasses.
- A paper describing the new species *Rhipilia psammophila* was submitted to *Australian Systematic Botany*.
- 338 specimens of marine algae were added to the WA Herbarium collection.
- The plenary presentation *William Henry Harvey and his Australian Seaweeds* was given at the International Seaweed Symposium in Hobart.
- A red seaweed common in the Swan Estuary has been identified by DNA sequencing as *Gracilaria transtasmanica*, ending decades of uncertainty.

**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**

- Publication of papers describing new and existing genera, species and other categories.
- Undertake further taxonomic studies of Western Australian species of the red algal genus *Gracilaria*.
- Undertake further taxonomic studies of the potentially invasive red algal genus *Hypnea*.
- Undertake taxonomic assessments of turf algae, including descriptions of potentially new species of filamentous red algae.

## 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, C Ely

**Context**

This project is a direct successor to the *Western Australian Marine Plants Online* and will provide descriptions of the entire currently known Western Australian marine flora 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, 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**

- Data for 339 algal specimens, newly added to the Western Australia Herbarium collection, are now available via *Florabase*, improving taxonomic and distribution knowledge concerning the Western Australian marine flora.
- 43 new names have been added to the census of Western Australian flora.
- 857 existing WA Herbarium records of marine flora have been edited to update synonymy, cited specimens, and family changes.
- Scoring of character states for the interactive key is nearing completion.
- Additional fact sheets describing morphological and reproductive features have been prepared for inclusion in the interactive key, to assist in character recognition.
- Numerous additional *in situ* (particularly from the Perth region and Coral Bay) and microscopic images of marine algae have been taken.

**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 and practices, and threats to biodiversity.
- Provision of a readily available web-based information system will facilitate easy access by managers, researchers, community and other stakeholders to marine plant species inventories and up-to-date names.

**Future directions**

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

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

SP 2009-006

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

**Context**

Western Australia has a rich flora that is far from fully known. New species continue to be discovered through the taxonomic assessment of herbarium collections, floristic surveys and the botanical assessment of mineral leases. There are more than 1062 putatively new and undescribed taxa on Western Australia's vascular plant census, almost half of which are poorly known, geographically restricted and/or under threat (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 phrase-named plant taxa, particularly Threatened and Priority Flora and those vulnerable to future mining activities.

**Progress**

- 19 new taxa were named and described in Ericaceae, *Acacia* and *Lambertia*, 17 of which were conservation-listed, including two threatened taxa.
- Morphological assessment of species complexes of *Geleznowia* and *Isopogon* were completed in conjunction with genetic analysis.
- Joined BushBlitz surveys and undertook targeted field work to progress taxonomic research. Investigations on *Lasiopetalum*, *Goodenia*, *Thysanotus, Arthropodium* and *Stylidium*were carried out and substantial progress made on associated manuscripts.
- Five putatively new and poorly known species were added to the State's vascular plant census under a phrase name.

**Management implications**

- The provision of names, scientific descriptions, illustrations and associated data will enhance the capacity of conservation and industry personnel to identify these new species, thereby improving conservation assessments and effective management.

**Future directions**

- Identify and formally describe new taxa of conservation significance.

## Translocation of critically endangered plants

SP 2001-004

L Monks, R Dillon, M Byrne

### Context

The contribution of translocations (augmentation, introductions, reintroductions) of threatened flora to the successful recovery of species requires the 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 priorities for translocation.
- Develop detailed protocols for assessing and predicting translocation success.
- Establish a translocation database for all threatened plant translocations in Western Australia.

### Progress

- Monitoring was undertaken for two multi-species seed orchard sites for threatened plant species in the Stirling Range that were impacted by fire and *Phytophthora* dieback. This monitoring data is being included in a manuscript on the recovery of threatened Stirling Range plant species following fire.
- A translocation proposal to augment a population of *Banksia cuneata* was developed and approved. Seedlings were planted at the new translocation site, site infrastructure (fence and irrigation system) was installed and initial monitoring completed. This project was developed in collaboration with the Peel-Harvey Catchment Council and private property owners.
- Infill planting was undertaken at one translocation site for *Banksia cuneata* to boost the number of plants.
- A paper describing the analysis of flora translocation data from 22 years of plantings and examining factors that contribute to translocation success was published in *Plant Ecology*. The findings from this work support the use of fences to exclude herbivores and watering to improve the likelihood of reproduction.
- A chapter describing challenges for flora translocations and lessons learnt was published in the book *Ecological Restoration*.

### Management implications

- Successful translocations led to the improved probability of persistence for threatened flora, particularly critically endangered plant species. Ongoing monitoring of translocations is providing information on the success of methods used and the probability of long-term success, and informs other flora translocation projects.
- Further development of success criteria and methods for analysing long-term success, such as the use of population viability analysis (PVA), mating system analysis and genetic variability analysis, will ensure completion criteria are adequately addressed and resources can confidently be allocated to new translocation projects.
- Improved awareness of best-practice translocation methods by departmental staff and others undertaking such work leads to greater translocation success.

### Future directions

- Develop a PVA model for translocated and natural populations of *Acacia cochlocarpa* subsp. *cochlocarpa* using demographic data already collected.
- Continue to monitor plant survival, growth and seed production at recently-established translocation sites for *Grevillea calliantha*, *Banksia cuneata* and threatened Stirling Range flora.
- Undertake monitoring of vegetation plots at one *Banksia cuneata* translocation site, to assess impacts of translocation activities on associated vegetation.

- Establish monitoring of *Grevillea maxwellii* translocation and natural populations in order to develop a PVA model.

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

SP 2001-001

M Byrne, R Binks, L Monks, R Dillon, J Filipe, A Crawford

### 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.
- Assess patterns of genetic diversity and population differentiation in rare species to assess previous management actions and inform future actions.

### Progress

- A study to assess mating system variation and genetic diversity for two translocated *Banksia brownii* populations and benchmark these measures against seven natural populations has been completed. In addition, a pollination study on a subset of four of the natural and one of the translocated populations of *Banksia brownii* to assess the adequacy of pollination in the translocated population, has also been completed. Key findings were the use of multiple source populations for translocation resulted in higher reproductive output and equivalent levels of genetic diversity compared to reference wild populations. However, the translocated population had the highest rates of selfing, which could potentially lead to the long-term erosion of genetic diversity through unfavourable patterns of mating. The results of these studies have been published in the *Australian Journal of Botany*.
- Assessment of fitness traits is ongoing in a common garden experiment involving 1100 seedlings of *Banksia brownii* from montane and lowland natural populations and a translocated population, to examine trait differences between montane and lowland populations, and implications for population mixing, and to benchmark the performance of the translocated population. Initial findings have shown that outcrossed seedlings have higher fitness than self-pollinated seedlings and management of the translocated populations should focus on ways to improve pollinator services to improve long-term translocation success. Two manuscripts have been prepared from this work. One is in draft and the second is in review for publication in *Restoration Ecology*.
- Data analysis has been completed on genetic diversity data for natural and translocated populations of *Acacia cochlocarpa* subsp. *cochlocarpa* and *A. cochlocarpa* subsp. *velutinosa*. This study will benchmark genetic diversity in translocated and natural populations of *A. cochlocarpa* subsp. *cochlocarpa* and assess genetic structure across the range of both subspecies. Key results include levels of genetic diversity in two translocated populations are equivalent to the single wild source population and two other wild

populations, indicating the use of the single seed source for the translocation was appropriate. Patterns of genetic structure across the two subspecies generally indicate significant differentiation between them. An exception was a population of *A. cochlocarpa* subsp. *cochlocarpa* near Dowerin that showed less differentiation from the subsp. *velutinosa* whilst fitting the morphological description of subsp. *cochlocarpa*. A manuscript describing this study is in preparation.
- Analysis of genotyping and mating system data has been completed for *Banksia anatona,* to assess mating system performance and genetic diversity in a translocated population compared to natural populations. Results showed genetic diversity of two translocated populations were equivalent to three wild source populations and the mating system estimates for one translocated population (second translocation not assessed) largely reflected those of wild populations. The species showed a predominantly outcrossing mating system. A manuscript describing this study is near completion.
- Genetic and taxonomic revision of subspecies within *Lambertia orbifolia* has been completed. This work used earlier genetic analysis of *Lambertia orbifolia* and combined this with a genetic study of a recently discovered population and measures of herbarium specimens to formally describe three subspecies. This taxonomic revision was published in *Nuytsia*.
- Genomic analysis of two species, *Banksia cuneata* and *Chorizema humile*, is currently underway to assess genetic diversity and population differentiation across extant populations, both natural and translocated, as well as to assess the genetic diversity of seed collections currently stored in the Western Australian Seed Centre.
- Genomic analysis of *Tetratheca butcheriana* is currently underway to assess fine scale patterns of genetic diversity and population differentiation across its very narrow range in the Pilbara.

**Management implications**
- Assessment of genetic variation and mating system parameters will inform prescriptions for the prevention of inbreeding and maintenance of genetic variation in small fragmented populations of rare and threatened plants, and will facilitate strategies for managing inbreeding and loss of genetic diversity during translocation programs involving species such as *B. brownii, L. orbifolia, A. cochlocarpa* and *Schoenia filifolia.* For species in resource-rich areas, such as *T. butcheriana* in the Pilbara, information on genetic diversity and gene flow patterns will also inform impact assessments for future mining activities.

**Future directions**
- Finalise mating system and genetic diversity studies on translocated and natural populations of *B. brownii*, *A. cochlocarpa*, *B. anatona, B. cuneata* and *C. humile*.
- Develop and implement a monitoring plan for the *L. orbifolia* common garden experiment.
- Finalise and report on the genetic study of *T. butcheriana*.

## The population ecology of critically endangered flora

SP 2000-015

C Gosper, M Chick, R Dillon

**Context**

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

**Aims**
- Determine the critical biological factors and the relative importance of contemporary ecological interactions and processes in limiting population viability and persistence, particularly for critically endangered species

and other key plant species occurring in TECs.
- Improve understanding of patterns of distribution of threatened and priority flora, their ecological, evolutionary and genetic traits, and how these traits mediate susceptibility to key threats.

**Progress**
- Continued monitoring of the Eastern Stirling Range Montane Heath and Thicket TEC and associated threatened flora following the May 2018 and December 2019 bushfires. Data were analysed to quantify the consequences of the bushfires and interacting threats on threatened flora populations and the TEC, and the effectiveness of threat mitigation measures such as phosphite spraying to reduce the impact of *Phytophthora* dieback and fencing to exclude herbivores.
- Implemented recovery actions implemented for Stirling Range threatened flora and TECs including phosphite applications, rabbit control, installation of fencing, seed collections and new plantings of three species in two existing seed productions areas.
- Stirling Range threatened flora, TEC, fire-dieback interaction and State government response case studies featured across four chapters of the book *Australia's Megafires*, published by CSIRO and forming part of a comprehensive review of the effects of the 2019-20 bushfires on all components of biodiversity.
- Fire regime and plant trait data were contributed to national desktop syntheses of the putative consequences of the 2019-20 bushfires on plant species and ecological communities, published in two papers in *Global Ecology and Biogeography*.
- Initiated research testing whether threatened montane Stirling Range flora have shifted in distribution towards more mesic climate refugia following the 2018 and 2019 bushfires, associated with ongoing climate warming and drying across the region.

**Management implications**
- Studies of the effects of fire interval, *Phytophthora* dieback, browsing and threat mitigation actions on population trends for 26 threatened and Priority flora in the Stirling Range National Park provided critical information on impacts of 2018 and 2019 fires and priorities for species recovery through *in situ* threat management and translocation.
- Demographic studies and experiments investigating the impact of disease, fire intervals and patchiness, and environmental weeds on threatened flora will provide critical information for supporting species recovery.
- Spatial analysis of threatened and Priority flora and threats identified ancient, infertile uplands and surface geologies of limited extent within 300-500 km of the present-day coast as hotspots for flora conservation and management. Flora on these geologies have higher frequencies of traits that elevate their susceptibility to extremes in fire interval and *Phytophthora* dieback. Differences in patterns of spatial distribution of data-deficient and threatened flora suggest that conservation activities directed at mitigating threats to natural populations of threatened flora will not be effective for the conservation management of a significant proportion of the data-deficient flora. This finding emphasises the value of threat mitigation actions in locations supporting numerous data-deficient flora.

**Future directions**
- Continue demographic studies.
- Complete the analysis of spatial patterns of threat intensity in the Southwest Australian Floristic Region to define hotspots and priority areas for flora recovery and management.
- Develop a model of vegetation condition in Fitzgerald River National Park so that temporal and spatial trends in *Banksia* decline can be assessed and monitored.
- Analyse data on flora persistence in fragmented landscapes to identify plant trait, landscape context and land management correlates of population persistence.

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

SP 1999-010

A Crawford, S Dudley, A Monaghan

## Context

Seed conservation is a specific and targeted action to conserve biodiversity and entails banking 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 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 72 seed collections (32 species) were banked at the Western Australia Seed Centre, Kensington; 70 of these collections (30 species) were listed as critically endangered, endangered, or vulnerable (threatened flora), two of these collections (two species) were priority flora.
- 27 seed collections from 10 threatened species and two priority species were collected for the Rare Bloom Project™.
- Six seed collections from four threatened species were collected for the Conservation of Critically Endangered Species (Australia) project, a collaboration between DBCA, The Royal Botanic Gardens, Kew (UK) and the Australian Seed Bank Partnership.
- Three seed collections from three species were collected for the Safeguarding Midwest Flora project, a collaboration between DBCA and Northern Agricultural Catchment Council as part of the Threatened Species Strategy Action Plan funded by the Australian Government.
- The seed bank now contains 6232 collections (1927 taxa) representing 349 threatened flora, 749 Priority flora and 829 flora for ecological restoration.
- 235 germination tests were conducted.
- 26 accessions were used to produce seedlings of nine threatened species for use in translocation.
- Seedlings of one species, *Schoenia filifolia* subsp. *subulifolia*, were planted into a seed production area (SPA) at Woodlupine Primary School, whilst seed of the same species was provided to continue a SPA at the Central Regional TAFE in Geraldton. In it's first year the Geraldton SPA yielded over 700g of seed from the 80g used to establish the site. Some of this seed is now being used to augment a translocation of the 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 threatened flora and for departmental restoration projects.
- Provision of seed biology and ecology data increases the success of threatened flora recovery actions, particularly through knowledge of how pre-treatments may stimulate seed germination.

- Re-testing of old collections (>10 years) is showing that the storage conditions at the Western Australian Seed Centre are maintaining the viability of most tested collections. Viability declines, whilst uncommon, have occurred, highlighting the importance of ongoing monitoring at regular intervals to the management of *ex situ* seed collections.

**Future directions**

- Ongoing collection of seed of threatened flora, focussing on species either not represented in the seed bank or with low quantities of banked seed, for long-term conservation and use in translocations.
- Complete a review of the long-term (>10 years) storage performance of seed collections held in the Western Australian Seed Centre.

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

SP 1998-003

M Byrne, R Binks, D Bradbury, B Anderson, C Gosper

**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 the conservation status of rare and threatened taxa. Genetic analysis can inform the conservation and biosystematics of these taxa.

**Aims**

The primary aim is to provide genetic information for the conservation and management of Western Australian flora, especially rare flora. Current projects aim to:

- Determine the phylogenetic relationships among *Leptospermum* species and examine the genetic boundaries within a large Western Australian species complex.
- Determine the spatial extent of two identified genetic lineages within *Eucalyptus salubris* and investigate genomic relationships among nine species within the gimlet complex.
- Determine the genetic relationship between *Verticordia spicata* subsp. *spicata* and the critically endangered *V. spicata* subsp. *squamosa.*
- Determine the genetic relationship between the disjunct populations of three species (*Daviesia obovata, Gastrolobium crenulatum* and *Andersonia echinocephala*) that occur exclusively in the Stirling Ranges and Fitzgerald River National Parks.
- Determine the genetic relationships among several subspecies and unnamed entities within *Conospermum caeruleum*.
- Determine the genetic relationships within four species complexes (*Geleznowia*, *Isopogon*, *Synaphea* and *Wurmbea*) as part of the Genomes of Australian Plants (GAP) initiative.
- Assess the taxonomic status of *Rhagodia* sp. Hamersley (M. Trudgen 17794) in relation to *R. eremaea* in the Pilbara.
- Determine the genetic relationships among several subspecies and species in the *Grevillea brachystylis* complex.
- Assess the hypothesised hybrid status of three threatened *Eucalyptus* species, *E. crispata*, *E. leprophloia* and *E. pruiniramis.*
- Determine the genetic relationships among 12 species of the mulga (*Acacia aneura*) species complex.

**Progress**

- A taxonomic revision of Western Australian species of *Leptospermum* based on the genomics results has been published in *Nuytsia*.

- Genomic analysis of the *C. caeruleum* species complex is complete, showing that at least three distinct species should be recognised, with three management units within one of those species. A paper has been published in *Biodiversity and Conservation*.
- Genomic analysis of the nine species of the gimlet complex is almost complete and a manuscript is in preparation.
- Genomic analysis and morphological assessment of *V. spicata* has shown that there is a lack of evidence to support the continued recognition of *V. spicata* subsp. *squamosa* as a subspecies distinct from *V. spicata* subsp. *spicata*. A manuscript is near completion.
- Genomic analysis of *D. obovata* is complete, showing that the populations within each national park are highly divergent from one another and that the populations within each national park are quite distinct. DNA extractions are underway for the remaining two species.
- Genomic analysis is largely complete for the four species complexes in the GAP project. Two of the studies are almost finished (*Geleznowia* and *Isopogon*) and manuscripts have been submitted for publication. Morphological analysis of *Wurmbea* is underway, and further analysis of *Synaphea* is being undertaken given complexities around clonality.
- Field sampling and sequencing for the *G. brachystylis* group is complete and data analysis is progressing.
- Field sampling and sequencing for the *Eucalyptus* hybridisation project is complete and data analysis is progressing.
- Field sampling of *Rhagodia* populations is largely complete and DNA extractions are underway.
- Sampling for the *Acacia aneura* complex is almost complete.

**Management implications**

- Assessment of the genetic relationships among *Leptospermum* species has informed taxonomic revision of the group, which provides a solid foundation for the appropriate use of natural resources for honey production.
- Resolution of lineages in *E. salubris* and genetic relationships among all nine species in the gimlet complex will provide a basis for taxonomic revision and inform seed sourcing for restoration activities in regions where *E. salubris* is typically used.
- Resolution of the taxonomic status of *V. spicata* subspecies will allow re-assessment of the need for conservation listing and resource allocation to the management of *V. spicata* subsp. *squamosa*.
- Genomic assessment of *D. obovata, G. crenulatum* and *A. echinocephala* will inform suitable management options for these highly disjunct threatened species.
- Genomic analysis of the *C. caeruleum* subspecies has provided a basis for taxonomic revision of this highly morphologically variable group.
- Genomic analysis of the four species complexes in the GAP project will resolve the species within each group and identify those with conservation concerns to enable conservation listing and appropriate management.
- Genomic analysis of *R.* sp. Hamersley will facilitate a formal species description if needed, and in conjunction with the survey data from sampling, will allow its conservation status to be assessed.
- Genomic analysis of the *G. brachystylis* complex will delimit taxa, allow re-assessment of conservation statuses and provide clarity to on ground conservation officers.
- Genomic assessment of putative hybrid origins for the three *Eucalyptus* species will provide clarity on the need for conservation listing and the resources allocated to their management.
- Genomic assessment of the *A. aneura* complex will provide support for delimiting species amongst the challenging morphological taxonomy of this complex group and allow appropriate management of these species in the arid zone.

**Future directions**

- Finalise papers on the gimlet and *V. spicata* datasets.
- Complete extraction, sequencing and analysis for *G. crenulatum* and *A. echinocephala*, and write a combined paper for all three disjunct South Coast species.
- Complete morphological assessments for *Wurmbea,* complete genomic analyses for *Synaphea* and write papers for these projects.
- Complete extraction, sequencing and analyses of *Rhagodia* samples.
- Finalise data analyses for the *G. brachystylis*, *Eucalyptus* and *A. aneura* projects and write papers for these datasets.

# Ecosystem Science

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

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

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

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

## Evaluating the application of eDNA and metabarcoding as biodiversity and monitoring tools

SP 2020-068

J Hyde, L Dugal, A Wills

### Context

Ecological monitoring is a key element of adaptive conservation management, but can be resource intensive. In recent years, techniques such as camera traps, audio recorders and satellite tracking have improved effectiveness of monitoring programs. Metabarcoding and environmental DNA (eDNA) are emerging technologies that may be used to enhance environmental monitoring. While no single tool can provide all the information necessary for monitoring, eDNA has some advantages over other methods in some situations. For example, significant taxonomic expertise is often required to identify taxa, especially invertebrates, but such expertise can be difficult to obtain. Additionally, some existing methods are not ideal for detecting elusive or poorly known taxa and can be laborious. eDNA may overcome some of these limitations, and this project examines how eDNA can be effectively used as a monitoring tool, complementing existing methods and projects for biodiversity conservation.

### Aims

- Apply eDNA and metabarcoding methods to a range of survey and monitoring projects to evaluate whether they can effectively replace or complement traditional ecological sampling.

### Progress

- Wetlands eDNA kits were tested at two Ramsar wetlands and barcoding of invertebrates commenced.
- Samples of zooplankton from the Pilbara have been extracted and sequenced and bioinformatic analyses have been completed.
- Sequence data was analysed from soil microbial samples collected in the Yarragil experimental thinning catchments, and a poster was presented at the American Society for Microbiology Conference. Shotgun data is undergoing bioinformatic analysis.
- A collaboration with the Cane Toad management group has developed an eDNA sampling protocol for tracking the movement of the cane toad front and samples are being analysed on an ongoing basis.
- Samples of dry wetland sediment from the Badimia Conservation Reserves were collected for extraction of DNA to detect microinvertebrate resting egg banks.

### Management implications

- Results of these projects will help inform how eDNA can be applied in future monitoring projects.
- The development of standard protocols for eDNA collection, extraction and sequencing could contribute to standardisation across the department and potentially other agencies as this approach starts to be implemented.
- The development of reference barcode libraries will improve species discovery, knowledge of species' ranges and ecological requirements and provide greater understanding of ecosystem conservation values.
- Thinning of stand density in the Yarrigil catchments does not affect soil microbiome composition below and between trees, suggesting that range of jarrah forest soil processes may not be affected by thinning, but the open space microbiome will expand as the canopy opens.
- eDNA has been added to the cane toad detection toolkit and is being used at the invasion front.

### Future directions

- Continue to add to the barcode libraries as opportunities arise.
- Synthesise the results of the freshwater eDNA projects and produce guides for use in management.
- Write a paper on the responses of soil microbiomes to ecological thinning.
- Publish analyses the utility of eDNA as a forest ecosystem monitoring tool.

## Lifeplan: A planetary inventory of life

SP 2020-009

A Pinder, G Barrett, A Barrett, M Brotherson, R Glowicki, K Quinlan

### Context

Lifeplan is a global biodiversity survey project funded by the European Research Council and led by the University of Helsinki. As a fundamental data platform, Lifeplan will generate standardised, global data on a range of species groups, allowing quantification of variation in ecological communities at spatial scales from 0.1 km to 10000 km across hundreds of thousands of species. This project is establishing 100 sites globally, with additional denser sampling in the Nordic countries and in Madagascar. Each of the 100+ global sites will consist of paired urban and natural locations. Perth has been selected as one of the global sites, with plots located in woodlands dominated by *Banksia* and *Casuarina* in Lowlands Nature Reserve and Kings Park. In addition to investigating global patterns in biodiversity, the project aims to scale up the use of efficient biodiversity monitoring tools (machine learning analysis of ecoacoustics and camera trapping data, and metabarcoding of aerial spores, soil

fungi and flying insects). The project will be carried out over six years, with sampling alternating between the Lowlands and Kings Park locations.

**Aims**

- Gain an understanding of the application and effectiveness of novel biodiversity survey methods through participation in a global project.
- Survey and contrast the biodiversity values of a large semi-rural nature reserve and a large urban bushland with similar dominant overstorey vegetation.
- Improve understanding of the broader biodiversity values of a Threatened Ecological Community (*Banksia* woodlands of the Swan Coastal Plain).

**Progress**

- Twelve months of sampling was completed at Kings Park and the equipment moved back to the site at Lowlands Nature Reserve.
- Samples of spores from the cyclone sampler and of soil are being sent to the Swedish University of Agricultural Sciences and insect samples to University of Guelph in Canada.
- Audio and camera trap imagery are being transferred to the project headquarters in Helsinki via a cloud file transfer service.
- The project team contributed to the audio machine learning process by identifying call samples from the Perth site.

**Management implications**

- Involvement with this global project will provide Biodiversity and Conservation Science and the Botanic Gardens and Parks Authority (BGPA) staff with an improved understanding of the capacity for newer technologies for efficient survey and monitoring of biodiversity.
- The monitoring will provide insights into threatening processes such as urbanisation, feral animals and fire. In particular, it will provide BGPA with an understanding of how management of Kings Park has allowed retention of biodiversity inhabiting *Banksia*/*Casuarina* dominated woodlands on the Swan Coastal Plain.
- Information collected add to an understanding of temporal patterns in biodiversity values of a threatened ecological community (banksia woodlands of the Swan Coastal Plain), which can be used to design monitoring programs and management actions.

**Future directions**

- Continue monitoring at Kings Park and Lowlands Nature Reserve.
- Compile reference libraries of faunal images and assist with providing training data for machine learning of bird calls.
- Undertake botanical surveys at the Lowlands and Kings Park sites to add to the information base for these sites and add context to analyses.

## Tracking the condition of Ramsar wetlands in Western Australia

SP 2020-007

M Venarsky, B Huntley, G McGrath, A Pinder, A Barrett

**Context**

The management of Ramsar wetlands on Western Australia's conservation estate is the responsibility of DBCA, in partnership with external organisations. The department coordinates documentation on the wetlands' condition and reports to the Commonwealth Government for reporting to the Ramsar Secretariat. Like many wetlands

globally, Western Australia's Ramsar wetlands are threatened or currently being affected by various factors. These include water resource development, agriculture and urban development, invasive species, mining, plant diseases, salinisation, and climate change. This project aims to undertake monitoring of the State's Ramsar wetlands to improve reporting capabilities and determine efficient monitoring techniques for adaptive management programs.

**Aims**

- Undertake monitoring of Ramsar wetlands to enable effective management and reporting on their condition.
- Understand spatial and temporal patterns in wetland hydrology, water quality and vegetation structure as primary drivers of wetland biodiversity.

**Progress**

- Completed the field component for a project describing the hydrology and salt budget for Lake Clifton (Peel-Yalgorup site), particularly with respect to the thrombolite TEC.
- Conducted waterbird surveys at Thompsons and Forrestdale Lakes, Lake Gore and Lake Warden systems.
- Conducted fish survey in the Muir-Byenup and Lake Warden systems.
- Conducted field work for the second year of baseline aquatic invertebrate survey of the Peel-Yalgorup system, processed most of the samples and invertebrate identifications are underway.
- Conducted multiple UAV LiDAR test acquisitions and have developed processing pipelines for point cloud data.
- Sampled aquatic invertebrates in Lake Wheatfield and Thompsons Lake using traditional methods for comparison with eDNA kits.
- Provided data and advice into multiple Ramsar wetland management and reporting frameworks.
- Assisted Southcoast NRM and Rangelands NRM with concept plans to acquire funding to support research and monitoring programs at: Eighty Mile Beach, Roebuck Bay, Lake Gore, and Lake Warden.

**Management implications**

- Direct measurements of habitat quality and quantity as surrogate indicators of broader wetland health and biodiversity values will improve the ability to report on limits of acceptable change in the Ecological Character Descriptions.
- Monitoring of waterbird populations will provide consistent data on which to base assessments of limits of acceptable change.
- Site specific monitoring and research will provide local managers with information to assist with adaptive management of Ramsar wetlands.

**Future directions**

- Finalise UAV protocol and begin conducting vegetation monitoring at Ramsar sites.
- Conduct fish and invertebrate surveys at Muir Byenup, Lake Gore, and Lake Warden systems. Conduct the final year of baseline aquatic invertebrate surveys at the Peel-Yalgorup Ramsar site.
- Continue processing aquatic invertebrate samples.
- Organise waterbird survey for Lake Argyle, Lake Kununurra, and Parry's Lagoon in northern Western Australia.

## Understanding the implications of a drying climate on forest ecosystem function to inform and improve climate change adaptation

SP 2019-068

K Ruthrof, R Van Dongen, G McGrath

**Context**

Little is known about the effects of climate change on our forest ecosystems. A broader understanding of the range of effects that climate change has on forest ecology and functioning is required to predict how forest

ecosystems will respond to a future climate and extreme weather events. By increasing our understanding, management intervention techniques may be explored that could reduce the severity of changes to forest ecosystems. The Draft Forest Management Plan 2024-2033 indicates that research will be prioritised to address knowledge gaps related to forest conservation, forest health and forest management for climate mitigation and adaptation strategies. Responding to current impacts of climate change on forest biodiversity and resilience, and forecasting future impacts, will be underpinned by knowledge and understanding of mitigation and adaptation actions.

**Aims**

- Understand the impacts of climate change and extreme events on structure, composition and functioning of forest ecosystems in southwestern Australia.
- Investigate responses to ecological thinning in forest ecosystems.

**Progress**

- Examination of drought-affected northern jarrah forest sites using geophysics showed drought effects leading to lower cover by trees and shrubs in soils <20 m thick and increased likelihood of drought effect in soils <12m thick, while treeless areas had thin soils, <2m thick. A manuscript has been submitted to *Ecohydrology*.
- Surface fuels at the Munro ecological thinning demonstration site were collected and five different thinning treatments compared. Collection of LiDAR data via drone was also tested at Munro. Permanent plots were established, and canopy cover, and coarse and fine woody debris transects were measured at the Hamilton ecological thinning trial.
- Examination of impacts of fruit harvesting on fruit production of *Banksia grandis* has been completed, and a final report has been written. For the three forest blocks examined, there is evidence of ample production without an obvious harvesting effect.
- A collaborative study with the Department of Fire and Emergency Services was undertaken to examine the vulnerability of regrowth forests to high severity fire. As part of this, the 060 DBCA fire dataset is being updated. A final report is being written.

**Management implications**

- Quantifying soil thickness will help understand climate vulnerability across the forest and help prioritise sites for ecological thinning.
- Quantifying the ecological responses to different treatments at the Munro and Hamilton ecological thinning sites, such as canopy cover and fuels, will inform which treatment is effective in terms of reducing leaf area, protecting the forest from drought impacts, and fire hazard.
- Understanding how the microbial community changes across forest types, silvicultural treatments, and rainfall gradients will help prioritise ecological thinning activities.
- Examination of current *Banksia* fruit harvesting showed it is at sustainable levels.

**Future directions**

- Examine soil thickness via geophysical methods (electrical resistivity tomography) transects and canopy characteristics via Landsat data at key ForestCheck sites, and thinned catchments.
- Examine microclimatic differences across treatments at the Munro ecological thinning demonstration site and calculate potential fire behaviour. Examine soil compaction, canopy structure, and understorey diversity in response to different treatments at the Hamilton ecological thinning site.

## Investigating the causes of change in forest condition

SP 2019-048

K Ruthrof, R Van Dongen

### Context

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

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

### Aims

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

### Progress

- Analysis regarding longer term (30 year) vegetation cover trends and landscape patterns has been undertaken and additional field sites identified to examine longer term decline in cover.
- Field-based investigations of how remotely sensed data of vegetation cover changes relate to on-ground forest stand and site characteristics have been completed.
- A manuscript on forest cover changes in the northeast region over the long-term is currently being finalised.

### Management implications

- Techniques used for mapping of vegetation cover, and understanding which ecosystem types and locations in the landscape are associated with declining vegetation cover, have been incorporated into forest management policy and planning, and contribute to mapping forest health and reporting.

### Future directions

- Extend fieldwork further south to investigate sites with declining vegetation cover that have been identified via remote sensing to determine stand and site characteristics associated with decline.

## Hydrological function of critical ecosystems

SP 2016-005

J Rutherford, G McGrath, B Huntley

### Context

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

be collected and integrated with existing biophysical datasets and information to optimise the transferability of hydrological results and outcomes to other areas.

**Aims**

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

**Progress**

- A comparison of rainfall intensity in relation to groundwater recharge and lake inundation has been completed in Walyarta and is in preparation for publication.
- In the Greater Brixton Street Wetlands, results from a Nuclear Magnetic Resonance (NMR) survey in 2018 have been compared with physical properties of sediments to understand the connectivity between groundwater and claypans.
- A journal article describing the hydrodynamics of flooding mechanisms at Ashfield Flats Reserve is currently in review.
- Completed geophysics near Lake Cave and completed water sampling for eDNA which is currently with external collaborators for analysis.

**Management implications**

- A study of lake inundation and rainfall advises that intense rainfall in Walyarta produces longer lived lake inundations but only short-term benefits to groundwater, which under a changing climate may threaten the resilience of groundwater dependent flora and fauna.
- Claypans in the Greater Brixton Street Wetlands have a complex hydrology due to urbanisation, which can amplify the effects of localised flooding, erosion, salinity and drought. These threats will continue to be management challenges under a changing climate and planned developments.
- Presentations of the science of the hydrological study at Ashfield Flats Reserve have been delivered to several stakeholders and been synthesized as part of a public consultation process regarding the future of the site.

**Future directions**

- Complete journal paper on Walyarta organic mound spring geochemistry.
- Complete a journal paper on benefits and threats associated with groundwater and surface water interactions in the Greater Brixton Street Wetlands.

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

SP 2015-001

J Rutherford

**Context**

Changes in the hydrology of Toolibin Lake and the Lake Bryde catchments, due to land clearing, have resulted in these previously ephemeral freshwater wetlands developing a connection with deeper, saline groundwater and becoming degraded. A decline in average rainfall since the 1970s has seen a further decrease in wetland

health as surface water flows and wetland hydroperiods decrease in quantity and quality. Robust management decisions require the main hydrological driver(s) of change to be identified and spatial and temporal fluxes (water and solutes) to be characterised. This project will significantly advance hydrological studies at Toolibin Lake and Lake Bryde by making full use of the data collection and analyses undertaken to date to produce practical tools for answering the key hydrological management questions.

**Aims**

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

**Progress**

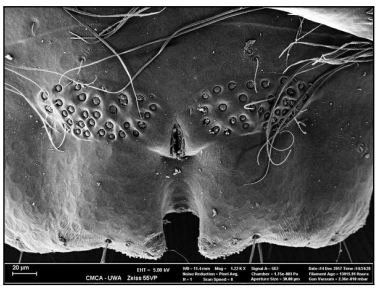
- The Toolibin Lake and groundwater models have been completed and linked to improve water balance results.
- Hydrological data from the Toolibin Lake winter inundation event (July 2021 to Dec 2022) have been modeled to map the distribution of different evaporite minerals on the lakebed.

**Management implications**

- The Toolibin Lake hydrological models have been completed and provide a platform to test the benefits of revegetating areas of Toolibin Lake and its local catchment.

**Future directions**

- Develop evaporite minerals maps of the Toolibin lakebed to assess current vegetation condition and review species selected for revegetation.
- Complete journal articles.




## Taxonomy, zoogeography and conservation status of aquatic invertebrates

SP 2014-025

A Pinder, K Quinlan

**Context**

Taxonomic knowledge underpins effective management of aquatic invertebrate biodiversity, including spatial patterning and trends over time in relation to threats. Over half of the species 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 the description of Western Australian aquatic invertebrate biodiversity and allow more consistent identification of specimens by departmental and external researchers.

### Progress

- Provided clam shrimp (Conchostraca) specimens from the Goldfields to a taxonomist in Germany, resulting in recognition of several new species.
- Sampled further moss beds on granite outcrops revealing new species of aquatic oligochaetes belonging to the Gondwanan family Phreodrilidae, some likely to have very restricted distributions, and all restricted to this habitat. Presented this work at the 15th International Symposium on Aquatic Oligochaeta in Brussels.

### Management implications

- The description of new species and the production of taxonomic tools, will allow more routine and consistent identification of this group, including in environmental impact assessment.
- Moss beds on granite outcrops contain unique invertebrate diversity not found in adjacent gnamma holes. This habitat can be damaged by recreational use including trailbikes.

### Future directions

- Undertake similar taxonomic work as required.

## 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

SP 2014-024

J Rutherford

### Context

Peat wetlands are relatively rare in Western Australia but constitute an important habitat for biodiversity where they occur, especially in the far south-west of Western Australia, providing refugia from seasonal and long-term drying for a range of geographically restricted flora and fauna. This includes rare wetland dependent orchids and a total of 21 priority plant species, short-range endemic aquatic invertebrates, the threatened Australasian bittern and south-west endemic fish.

Some peat wetlands in the Muir-Byenup System Ramsar site wetland suite are threatened by acidification and some have already acidified due to declining groundwater levels. Drying is also making these organic wetlands more prone to catastrophic fires. The peat also can contain 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

- Analyses of peat organic matter from Poorginup and Noobijup Swamps were included in a global publication as part of a international collaboration (Global Peat Microbiome Project).
- Outlines of two journal articles that discuss different approaches for investigating peat wetland resilience have been completed.

### Management implications

- Understanding responses of biodiversity values to peat wetlands activity will inform decisions on management treatments to reduce impacts on flora and fauna.
- Global research results indicate peat wetlands in southwestern Australia could be challenging to manage in agricultural areas due to relatively higher pH and nitrogen levels, and lower soil carbon and organic matter contents.

### Future directions

- Investigate peat wetland acidity treatments and the nature and extent of hydrological and hydrogeochemical processes of the Muir-Byenup Ramsar site.
- Communicate findings through the completion of journal articles.

## 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 management activities, such as timber harvesting and fire, on the terrestrial vertebrates of the jarrah forest is necessary for biodiversity conservation and development of ecologically sustainable forest management. This project began in 1994 and uses a before-after, control-impact study design to intensively investigate biodiversity responses to, and ecological consequences of disturbance by forest management.

### Aims

- Investigate the effects of management activities on terrestrial vertebrates in jarrah forest ecosystems.
- Provide information that helps improve ecologically sustainable management and biodiversity conservation in the jarrah forest.

### Progress

- Vehicle based spotlight monitoring of mammals on three standardised transects was conducted in Autumn (3 repeat surveys per transect). These surveys occurred immediately after a gum leaf skeletoniser outbreak that impacted approximately 100,000ha of the Upper Warren region during the summer. In some areas the outbreak has resulted in almost complete defoliation of all jarrah trees, a key source of food for ngwayir (western ringtail possum), in particular. The impacted area, includes the areas surrounding the three long-term monitoring transects in Greater Kingston. While no substantial declines were observed in the detection rates of the critically endangered ngwayir or koomal (brushtail possum) it is possible that significant declines may be observed in the coming year.
- A pedestrian-based spotlight survey within the Perup Sanctuary was conducted in November 2022 resulted in population estimates of 156 ngwayir individuals (95% Confidence Interval 127–192) and 350 koomal individuals (95% CI 272 – 452) within the 423 hectare predator-free sanctuary. Densities of both species did not differ between areas subject to prescribed burning 5 and 22 years ago. Competition from koomal may be limiting the distribution and abundance of ngwayir.

### Management implications

- Identification of decline in the ngwayir numbers in the Upper Warren region (including the Greater Kingston area) contributed significantly to the recent elevation of its conservation status to critically endangered.
- Information on the effects of the gum leaf skeletoniser outbreak, management and other environmental factors on terrestrial vertebrates and the factors responsible for changes in populations will lead to improved ecologically sustainable forest management practices and the conservation of biodiversity.

### Future directions

- Existing data will be analysed and prepared for publication.

## Western Australian flora surveys

SP 2012-005

M Lyons, A Markey, M Langley, A Barrett, R Binks

### Context

Flora surveys of targeted areas provide knowledge of floristics and vegetation pattern and structure for a variety of purposes, including provision of baseline biodiversity data, monitoring of management effectiveness, understanding distributions of threatened taxa, defining threatened and priority communities, determining suitability of vegetation for fauna translocation and conservation operations such as fencing and stock control. Recent surveys have included flora and vegetation surveys in the West and Central Kimberly and targeted flora surveys in Karijini National park.

### Aims

- Undertake targeted surveys to provide specific management advice, monitor long-term change in vegetation at specific sites and specific communities, or fill specific knowledge gaps.

### Progress

- Data for gypsum plant communities, sampled during a collaboration with Spanish researchers as part of the GYPWORLD project, has been compiled. A paper examining the biogeography of gypsum communities of southern WA is in preparation. Scoping is underway for a project to sample floristic sites for lichens in spring 2023.
- A reconnaissance survey of rainforest patches within Wunaamin NP was undertaken in collaboration with the Kimberley region. Floristic sampling and assessment of threatening processes was completed for a limited number of sites with others identified from the air. Specimen identifications are underway.
- Vegetation and flora surveys were completed for an area of UCL and crown reserves south of Exmouth to inform conservation planning for the coastal strip and Qualing Pool, and to determine the occurrence of conservation listed taxa for planned gravel pit extensions within Karijini National Park.
- A field trip was undertaken to the Badimia Conservation Reserves to scope a wetland biodiversity survey and mapping project, with the Badimia Aboriginal Corporation and Midwest region staff. A survey will be undertaken as rainfall and wetland filling allows.
- As part of DBCA's response to the Auditor General's review of salinity policy, populations of conservation significant flora and vegetation community types were overlayed on revised salinity mapping from CSIRO and DPIRD to determine salinity threat to flora and vegetation communities and the accuracy of the modeled salinity map.
- A project to reanalyse floristic community data for the Swan Coastal Plain commenced, in conjunction with regional and Species and Communities Program staff. Compilation of several large datasets has been completed and this has been updated for both nomenclature and taxonomy. Some preliminary analysis has been undertaken to ensure the integrity of the combined data.
- Analysis of the original Swan Coastal Plain dataset has been undertaken to provide advice in relation to wetland delineation of the Swan Coastal Plain in response to development applications.

- Curation and lodgement of survey plant specimens is ongoing. The lodgement of vascular aquatics from the Pilbara Biological Survey has been completed. Lodgement of priority listed taxa from recent survey work in the Ord Valley is progressing, along with advice supporting the priority listing of *Ipomoea argillicola*.
- Participated in the 2022 Wilinggin-West Kimberly Bush Blitz Expedition, sampling 14 sites, collecting 520 specimen vouchers and recording 283 plant taxa, and finding new populations for five conservation significant species.
- The third and final field trip was undertaken at Fortescue Marsh to acquire RPA photogrammetric imagery, LFA transects and rephotograph photopoints to test methodologies for a proposed vegetation monitoring manual that will be used by Aboriginal Ranger teams to monitor vegetation recovery following the installation of an herbivore exclusion fence.
- Genetic identification of unknown *Typhonium* specimens, based on previously developed barcoding markers, is being undertaken for DPIRD.

**Management implications**

- Analysis of salinity trends in relation to conservation significant flora, plant communities and wetlands from 40 years of south-west wetlands monitoring data, will inform DBCA's response to the Auditor General's report on salinity policy in WA.
- Reanalysis of floristic data for the Swan Coastal Plain will provide robust floristic classification that is central to the planning and approvals processes for assessing development and associated native vegetation clearing in the region.
- Floristic surveys at appropriate scales provide critical knowledge for conservation planning, reserve system design and environmental impact assessment.
- A monitoring manual for the Fortescue Marsh will enable Aboriginal Ranger teams to document vegetation condition, herbivore activity, the effectiveness of the herbivore exclusion fence and undertake management as required. This manual could be used by other Aboriginal Ranger groups with similar vegetation monitoring requirements in jointly managed rangeland protected areas.

**Future directions**

- In collaboration with European researchers, undertake analysis of GYPWORLD plant community data and commence reporting.
- Complete reporting of analysis of salinity trends.
- Complete analysis and reporting of the updated analysis of floristic data for the Swan Coastal Plain.
- Undertake floristic surveys as opportunities and needs arise, including survey of the Badimia wetlands.

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

SP 2011-020

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

This project addresses emerging issues for the next decade of forest management, including climate change and declining groundwater levels, interactions with pests and pathogens, and increased recognition of the role of

forests in maintaining global carbon cycles. The scope of this project has been broadened to include thinning response of even-aged jarrah stands, with all thinning experiments now covered by this 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 (for example, leaf water potential and leaf area index).

**Progress**

- A paper on the effect of thinning on growth and allometry of Karri was published in *Southern Forests.*
- A paper investigating the effects of above and below ground competition in jarrah and karri forests was published in *Forest Ecology and Management*.

**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 wildlife habitat or resilience to disturbance. Thinning is an important tool for managing streamflow and groundwater levels in forested catchments in the face of a drying climate as well as maximizing growth of retained trees. The current study indicates that stand basal area growth in even aged stands was optimised at retained basal ares of 13$m^2$ $ha^{-1}$.

**Future directions**

- Undertake periodic measurement of long term silvicultural experiments.
- Review findings and utilise data from long-term thinning experiments to inform future management options for maintaining forest health and productivity in a drying climate.

## Western Australian wetland fauna surveys

SP 2011-018

A Pinder, K Quinlan, A Barrett, D Cale

**Context**

Regional biological surveys provide analyses of biodiversity patterning for conservation planning at broader scales but sites in these projects are usually too sparse for use at a more local scale, such as individual reserves, catchments or wetland complexes. This project is designed to fill gaps within and between regional surveys by providing aquatic invertebrate biodiversity data and analyses at finer scales. Recent examples of such projects are wetland surveys in the Upper Fortescue catchment in the Pilbara, Lake Carnegie and Kimberley Mound Springs.

**Aims**

- Provide an 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 processing aquatic invertebrate samples from Pilbara river pools and finalising identifications, to determine impact of the invasive redclaw crayfish.
- Completed a report on collections of aquatic invertebrates sampled in 2014 and 2017 to understand aquatic invertebrate diversity in the Goldfields Region.
- Completed a report on the 'Julimar' wetlands as part of a study on aquatic invertebrate communities of the Wandoo Forest for Perth Hills District.
- Undertook a field trip to scope and plan a biological survey of wetlands on the Badimia joint managed lands in the Murchison District.
- Processed all samples from a resampling of Wheatbelt wetlands to examine responses of aquatic invertebrate communities to a high rainfall year, following a publication that showed a decline in diversity over a dry decade. Invertebrate identifications underway.
- Sampled aquatic invertebrates during a West Kimberley District field trip to Dragon Tree Soak (Great Sandy Desert). Processed samples, identified invertebrates and produced a report.

### Management implications

- New knowledge of the biodiversity values of arid zone wetlands' will assist with assessing the conservation status of species and communities and the environmental impact of mining and pastoralism, including direct removal of wetland habitat, altered hydrology, and degradation of fringing vegetation through grazing.
- Better descriptions of invertebrate communities can assist in understanding the habitat needs of threatened aquatic species such as the western swamp tortoise.
- Survey work is providing information to understand the threats posed by redclaw crayfish in the Pilbara and inform actions to minimise its spread.

### Future directions

- Publish a paper on invertebrate diversity in vegetated claypans of south-west Western Australia.
- Write a paper on biodiversity patterning across Kimberley springs.
- Publish combined results of numerous surveys of arid zone wetland aquatic invertebrates.
- Complete research into impacts of the invasive redclaw crayfish on aquatic communities in the Pilbara.

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

SP 2006-003

A Pinder, J Hyde, L Dugal, K Ruthrof, G McGrath, A Wills

### Context

FORESTCHECK has been a long-term monitoring program and results have been 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 was 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 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**

- Analyses of the biotic responses to harvesting and fire using data from 48 FORESTCHECK grids sampled twice between 2001 and 2012 have been published in *Forest Ecology and Management*.
- A manuscript has been drafted exploring the biotic responses to harvesting and fire in 16 Forestcheck sites sampled from 2013, in the Donnelly South and Sandy Basins jarrah forest ecosystems.
- Sequence data from soil and litter samples from the northern jarrah forest were analysed. A manuscript is in preparation showing that soil eDNA may complement rather than replicate invertebrate pitfall trapping.
- Soil DNA extractions from 41 FORESTCHECK sites were completed and are being sequenced with a cytochrome b primer to detect vertebrates.
- Microbial DNA was extracted and sequenced for the same soil samples and bioinformatic analysis is underway.
- Vertebrate barcoding using specimens from a variety of sources, including the Western Australian Museum, is progressing.
- Data for plants and invertebrates is being curated and converted to a format suitable for archiving and upload to corporate repositories.

**Management implications**

- FORESTCHECK has provided a systematic framework for evaluating the effects of silvicultural practices across a range of forest types and provided a sound basis for adaptive management.
- The project has demonstrated that harvesting had no impact on richness of most biological groups, but richness of cryptogams was higher in unharvested sites in the first monitoring round and richness of ground-dwelling vertebrates was higher in harvested sites in both rounds. Harvesting did not affect the composition of most biological assemblages, except that bird and cryptogam communities differed between unharvested and some harvested sites.
- Findings from the project continue to inform a variety of forest management policies and practices and contributed to a revision of silvicultural guidance documents and development of the draft Forest Management Plan 2024-2033 .
- The network of FORESTCHECK grids provides a framework for monitoring responses to disturbance events such as bushfires and extreme droughts, effects of stand density, and examining the impacts of a changing climate over the longer term.
- eDNA may provide an efficient tool for monitoring forest biodiversity and health.

**Future directions**

- Archive remaining FORESTCHECK project data in suitable repositories and ensure integrity of the grid sites. Publish a data paper promoting the value and use of FORESTCHECK data and the site network.
- Investigate further analyses of FORESTCHECK data such as for biogeographic patterning across the Jarrah Forest.
- Complete current eDNA based monitoring projects.

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

SP 2000-003

G McGrath, B Huntley, R Van Dongen

**Context**

This long-term experiment was established in 1999 to address part of Ministerial Condition 12-3 attached to the *Forest Management Plan 1994-2003* to monitor and report on the status and effectiveness of silvicultural measures in the intermediate rainfall zone (900-1100 mm $yr^{-1}$) of the jarrah forest to protect water quality.

### Aims

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

### Progress

- Continued monitoring of groundwater levels, streamflow, stream salinity, stream turbidity, rainfall, an automatic weather station and sap flow in Yarragil 4L, 4X, 6C, and Wuraming catchments in the Perth Hills District, 20km south of Dwellingup. This monitoring will indicate how thinning and the slow adjustment of the forest and hydrology in the decade or so post-thinning alters groundwater recharge and streamflow generation, informing riparian zone conservation, estimates of water demand by healthy thinned and unthinned forest.
- Monitoring of sap flow paused at Yarragil 4X and 4L with an upgrade of the data logger software and will recommence in July 2023. Sap flow provides a direct measure of tree water use, and a comparison of water use by similar sized trees with similar depths to groundwater at these sites provides an improved understanding of how thinning can mitigate water stress and improve forest health.
- A total of 2.4km of electrical resistivity geophysics surveys were conducted at Yarragil 4X and 4L which enabled imaging of soil depth and depth to bedrock in parts of these catchments. This data will be used in the future development of ecohydrological models of the catchments. These models can then be used to improve predictions of the effects of thinning on the hydrological response.
- Soil and stem samples were retrieved from Yarragil 4x (unthinned) and 4L (thinned 2019) and submitted for water stable isotope analyses. This sampling will continue through to the summer of 2023-24. This information, together with sap flow, will help inform how tree water use changes in response to thinning.

### Management implications

- Re-thinning of Yarragil 4L provides an opportunity to examine the effects of the silvicultural treatments on the groundwater and surface water hydrology, biodiversity, and vegetation structure and composition of the catchment. The experimental catchments at Yarragil provide the only continuous long-term record of the hydrological response of the headwaters of the jarrah forest to climate change and forest management practices enabling managers to better assess how riparian habitat might be conserved through forest management.

### Future directions

- Continue monitoring of groundwater levels, streamflow and water quality in the Yarragil catchments.
- Examine shifts in water use by plants resulting from thinning, using sap flow and isotope analysis.
- Prepare manuscripts on historical stream flow and water quality data, forest and hydrological responses to thinning, and groundwater responses to climate, forest management.

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

SP 1998-007

M Byrne, R Binks, M Millar, D Bradbury, N Delnevo

### Context

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

### Aims

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

sites in the Pilbara.

**Progress**

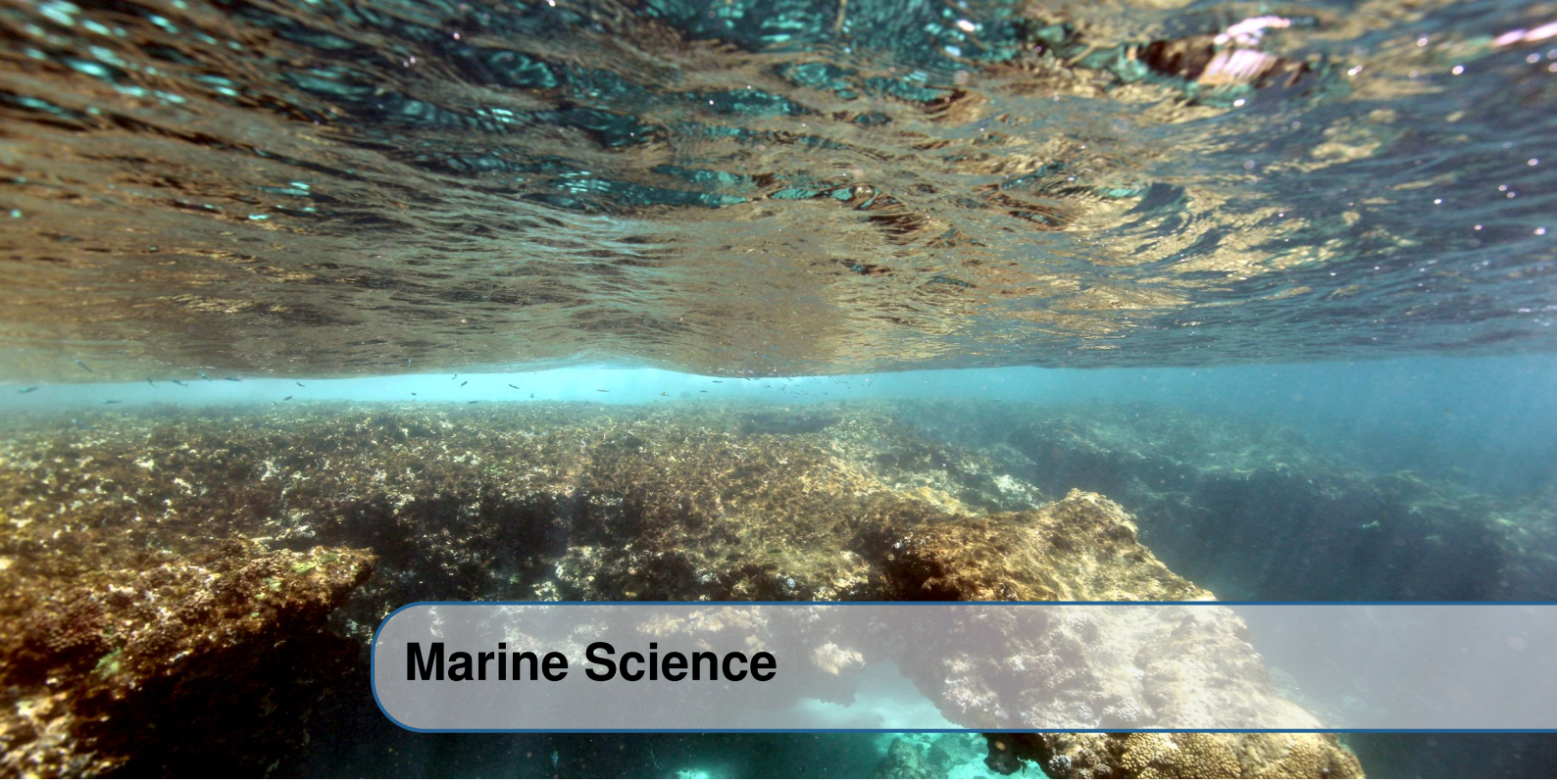
- Comparative analysis of two small *Acacia* shrubs with patchy distributions, *Acacia hilliana* and *A. spondylophylla,* show genetic differentiation among populations indicating some restrictions to gene flow in contrast to the widespread gene flow in the tree species. These results have been published in the journal *Ecology and Evolution*.
- Analysis of the small shrub *Mirbelia viminalis* shows genetic diversity similar to other widespread Pilbara species and genetic differentiation among populations, indicating some restrictions to gene flow as found for other Pilbara species of low stature. A paper has been published in the *Australian Journal of Botany*.
- Analysis of two widespread shrubs, *Petalostylis labicheoides* and *Indigofera monophylla,* showed higher genetic diversity in *I. monophylla* than in *P. labicheoides*, and slightly higher diversity was located in the Hamersley Ranges for both species. A divergent lineage of *P. labicheoides* was detected in the northeast Pilbara, and some structure in *I. monophylla* indicated higher levels of range-wide differentiation in these shrubs compared to widespread trees. This comparative analysis has been published in the journal *Annals of Botany*.
- Analysis of genetic diversity in *Senna glutinosa* subsp. *glutinosa* found very high levels of clonality within populations, and further analysis of seedlings revealed many of them to have identical genotypes as their mother plant, confirming apomixis as the dominant reproductive strategy, although some sexual reproduction was evident. Apomictic clones were distributed across the Pilbara landscape with no particular geographic pattern. This evidence of long-distance seed dispersal is likely driven by water movement following cyclonic activity. A manuscript is under review in the *Journal of Biogeography*.
- A synthesis manuscript is being prepared that summarises broad genetic patterns in eleven Pilbara species, focusing on seed collection and provenancing strategies for mine site restoration.

**Management implications**

- Understanding patterns of genetic diversity provides information for seed collection strategies in restoration and revegetation. Analysis of a range of species in the Pilbara provides information to support effective mine site restoration.
- While one tree species, *Eucalyptus leucophloia*, showed a pattern of ranges in the Pilbara being refugia, other species have not. The low level of differentiation in other tree species and large shrubs, such as *Corymbia hamersleyana, Acacia pruinocarpa*, *I. monophylla and S. glutinosa* subsp*. glutinosa* imply that seed resources for land rehabilitation and mine site revegetation programs for these species can be selected from a wide distributional range within the Pilbara. This is also similar for *P. labicheoides,* after excluding the divergent lineage.
- High genetic differentiation within species such as *A. hilliana*, *A. spondylophylla and M. viminalis* that have more restricted and patchy distributions indicate more limited seed collection zones are appropriate.

**Future directions**

- Finalise the *S. glutinosa* subsp. *glutinosa* paper.
- Finalise the synthesis paper to summarise the major genetic patterns seen across the Pilbara flora to inform broad recommendations for seed sourcing strategies used in mine site restoration.



# Marine Science

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

## Benefits of marine parks for marine fishes in a changing climate

SP 2021-040

S Bell, J Goetze, T Holmes, W Robbins, C Ross, S Wilson

### Context

To conserve WA's marine biodiversity, a network of marine parks has been established under the principles of being comprehensive, adequate and representative. These principles require knowledge of ecological assets over a statewide scale and are complicated by a changing environment. Finfish have been identified as a key ecological asset due to their high ecological and social values. Anthropogenic pressures are leading to shifts in the composition of fish assemblages, and it is unclear how well the current network of marine parks represents fish diversity. This project will combine DBCA finfish monitoring data with information collected by external collaborators to assess fish biodiversity inside and outside of WA marine parks over the last decade. This dataset will be used to describe statewide spatial and temporal patterns of finfish composition and distribution in relation to key pressures, to enable adaptive management and guide marine park planning.

### Aims

- Collate a statewide finfish dataset with key collaborators to enable biodiversity assessments of fish inside and outside of marine parks, over the last decade.
- Develop conversion factors that will enable the synthesis of DBCA finfish data (diver operated video, DOV)

with legacy datasets (underwater visual census, UVC) and emerging methods (remotely operated vehicle, ROV).
- Compare the composition, biodiversity and productivity of fish assemblages among marine parks relative to non-reserved locations.
- Assess if the composition, biodiversity and productivity of finfish assemblages within marine parks has changed over time and if any changes correspond with climatic events or are due to fishing pressure.
- Determine if these changes persist through time and whether patterns of change differ among parks located along the WA coast.

**Progress**
- Remotely operated video data for assessing finish has been collected in the North Kimberley and Lalang-garram marine parks, key data gap locations.
- Data is being uploaded to GlobalArchive (https://globalarchive.org), a centralised platform that allows users to store data in a standardised and secure manner, makes meta-data discoverable, and encourages collaboration and synthesis of datasets within the community of practice.
- A manuscript comparing fish data collected by diver operated video and a remotely operated vehicle (ROV) was published in *Estuarine, Coastal and Shelf Science.* Both methods sample fish assemblages in a broadly comparable way, although fish are less wary of ROVs, indicating less behavioural biases when compared to divers.
- A manuscript comparing fish data collected by underwater visual census, diver operated video, remotely operated vehicle and baited remote underwater video (BRUV) was published in *Estuarine, Coastal and Shelf Science.* We found that a combination of BRUVs, which sample a unique assemblage when compared to transect based methods and ROV will provide a comprehensive assessment of fish assemblages with improved operator health and safety and field efficiency.

**Management implications**
- Findings from this project will allow an assessment of how well the State's marine reserves represent biodiversity of fishes and associated ecological functions. This information can inform placement of new reserves and reconfiguration of existing reserves
- Temporal assessments will evaluate stability of marine fish diversity and functional values to determine if the current network of reserves will comprehensively and adequately represent fish assemblages in the future.
- Findings from the comparison of methods has facilitated the transition of the State-wide finfish monitoring program to remotely operated vehicles, which provide comparable data to legacy methods.

**Future directions**
- Continue data cleaning, formatting and uploading to GlobalArchive.
- Complete video analysis for stereo-ROV data collected in the Kimberley Marine Parks.
- Organise a workshop with key collaborators to undertake statistical analysis and write manuscripts.

## Primary productivity and energy transfer between marine ecosystems.

SP 2020-002

R Evans, M Moustaka

**Context**

Primary productivity provides energy that fuels food webs and is recognised as an important driver of local diversity and secondary production. Hence conservation planning often aims to identify where primary production is high; what systems, including their spatial arrangement, are most productive and how efficiently

productivity from these producers is transferred to other systems or consumers. While marine productivity is largely attributable to oceanic phytoplankton, productivity from benthic macrophytes becomes increasingly important in coastal food webs. However, the link between benthic productivity by vascular plants and algae and secondary production remains equivocal. Moreover, local variations in hydrology are likely to influence the supply of nutrients, temperature and light (caused by turbidity), all of which are fundamental determinants of primary productivity. This project will investigate rates of primary productivity and energy transfer in the shallow, turbid waters of the Dampier Archipelago.

**Aims**

- Develop an updated coarse benthic habitat map for the Dampier Archipelago and fine resolution benthic habitat maps for up to 16 sites.
- Develop fine scale oceanographic modelling of the Dampier Archipelago to provide water flow and retention data for interpreting spatial differences in productivity.
- Measure water quality parameters (total soluble solids, salinity, nutrients, Chlorophyll A) and assess how they vary spatially and temporally.
- Measure primary productivity in different marine habitats (mangroves, seagrass, seaweed and coral reef) and assess how rates vary among locations and between seasons in the Dampier Archipelago area.
- Measure abundance, diversity and growth rates of fish and benthic communities and assess how these relate to spatial variation in primary productivity.
- Measure abundandance and diversity of macroalgal epifauna and sediment infauna and assess how these relate to spatial variation in primary productivity.
- Measure stable isotopes of primary producers and secondary consumers, and use isotopic signatures to assess the extent of transfer from different primary producers to secondary consumer tissues and between different habitats.

**Progress**

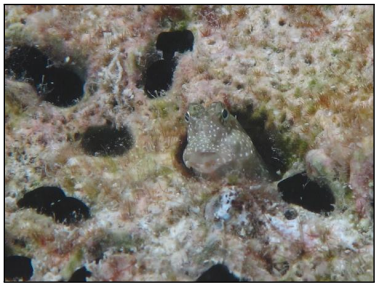
- Completed four field trips to the Dampier Archipelago.
- Second measurements of productivity were collected for mangroves (9 sites), seagrass (8 sites), and macroalgae (7 sites).
- Macroalgae-associated epifauna were collected (7 sites) over two seasons.
- Surveyed turf algae productivity at 9 sites.
- Completed the third and final surveys of adult and juvenile fish abundance and diversity (16 sites) in three habitat types.
- Completed laboratory and data analysis of 1600 stable isotope samples.
- Retrieved all oceanographic instruments and the development of fine scale hydrodynamic modelling is nearly complete.
- Sampling to evaluate water quality was finished and two additional sets of samples were sent for analysis, providing six temporal samples of water quality throughout the Dampier Archipelago.
- Third and final measurement of coral productivity using structure from motion photogrammetry has been completed.
- Following the 2022 heatwave in Dampier Archipelago, post bleaching surveys in July found that coral cover had declined at two sites.
- Repeated coral surveys during the heatwave in February found 10-80% of corals had bleached.
- Three years of photo transects quantifying benthic composition have been analysed.
- Analysis of 2021 fish stereo-DOV videos is complete. Analysis of 2022 and 2023 videos is currently in progress.
- Completed laboratory processing of first season of algal epifauna samples (65,000 individuals counted and identified).
- Completed processing and data analysis of the sediment for sediment grain size analysis, loss on ignition and stable isotope analysis for seasons 1 and 2.
- Completed processing and identification of the seasons 1 and 2 invertebrate infauna community.
- Submitted three manuscripts on fish distributions, coral feeding in turbid waters, and turf and fish productivity.
- Collected 130 eDNA samples across the Dampier Archipelago to understand seascape effects on biodiversity.

**Management implications**

- Identification of locations of high productivity may be used in spatial planning within the Dampier Archipelago and improve scientific advice relating to development projects in the area. Results will be transferable to planning in other locations with similar environmental conditions, by assessing which environmental factors correlate with high productivity.
- The lower turf algal productivity in Dampier Archipelago compared to other tropical coral reefs indicates lower herbivorous fish productivity. This is likely driven by turbidity, which may be natural or due to local coastal development in the Dampier Archipelago. Management should consider the impacts of future coastal development that may increase turbidity beyond natural variation along WA coastlines.
- As nearshore coral reefs experience greater turbidity with intensifying climate change and anthropogenic development, the knowledge that some scleractinian corals can alter their feeding strategies in response to turbidity levels, will allow for improved environmental impact assessment and predictive modelling for future coral reef conservation.
- Local habitat complexity was the strongest predictor of fish abundance, diversity, and assemblage composition in both coral and macroalgal habitats and this supports management approaches that prioritise the preservation of habitat complexity and incorporate the full range of habitats present in tropical seascapes.

**Future directions**

- Continue to collect data to inform the development of productivity and hydrodynamic models, and analysis of fish, coral and invertebrate communities.
- Collect second winter samples of macroalgae and measure mangrove and seagrass productivity for a third and final time.
- Estimate mangrove densities for productivity calculations.
- Finish analysing stereo-DOV and epifauna data and continue writing scientific publications.
- Finalise the hydrodynamic model and prepare resulting publications.



## Do marine reserves adequately represent high diversity cryptobenthic fish assemblages in a changing climate?

SP 2019-031

S Wilson, J Goetze

**Context**

Small-bodied fish (<5cm) typically account for ~40% of all described fish species on coral reefs and therefore are expected to represent a substantial proportion of fish diversity in the State marine reserves. Short life spans of these small fish also suggest they are important conduits of energy transfer in marine food webs and will respond more rapidly to environmental change and stressors than larger-bodied counterparts. This is especially pertinent along the WA coastline, where marine heatwaves have dramatically impacted habitat, and fishing may have reduced the abundance of small fish predators. Standard visual methods of surveying fish are not suitable for monitoring these small cryptobenthic fish (CRF). This project will investigate whether environmental DNA (eDNA) from water and sediment samples is a viable alternative to collecting with poison (clove oil) and visual approaches for assessing CRF assemblages. By collecting data from different habitats and management zones within marine parks, the project will also assess how effectively different techniques detect a change in CRF due to spatial variation in environment or management.

**Aims**

- Develop appropriate methods for measuring and monitoring CRF assemblages
- Compare CRF assemblages collected inside and outside of no-take sanctuary zones
- Compare CRF assemblages across a gradient of reef (habitat) types from high coral cover and complexity to reefs dominated by macroalgae with low complexity.

### Progress

- Fish assemblages have been surveyed inside and outside of two sanctuary zones within Ningaloo Marine Park, using clove oil and visual census. In addition, water and sediment samples were taken at each survey site for eDNA analysis.
- Fish collected with clove oil have been identified at the Western Australian Museum, and DNA from water and sediment samples has been extracted and identified.
- A manuscript describing and comparing fish assemblages from the different survey techniques is being prepared. Early results indicate that eDNA from water samples identifies more cryptobenthic fish species than other techniques.

### Management implications

- Comparison of different sampling techniques will identify appropriate methods for monitoring CRF and develop indicators that will rapidly inform managers of shifts in the condition of fish assemblages due to changes in habitat and fishing.
- These monitoring tools will be used to assess if management zones within the State's marine reserves adequately protect CRF in different marine habitats.

### Future directions

- Complete and submit a manuscript on comparing methods for surveying cryptobenthic fishes.
- Survey of CRF assemblages from different habitat types

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

SP 2018-136

S Strydom, K Murray, B Huntley, S Bell, T Holmes

### Context

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

### Aims

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

**Progress**

- The global database on seagrass structure, biomass and production was finalised and published in *Pangaea*, as well as the corresponding manuscript in *Earth System Science Data* .
- Indicators of seagrass condition collated across 60 sites in six WA marine reserves were analysed using a hierarchical Generalised Additive Model approach to assess the influence of environmental factors on trends in seagrass condition. Additionally, these data were used to inform four experiments investigating pressure-response thresholds for the impacts of dredging and ocean warming on seagrasses through the WAMSI-Westport project and ECU collaborations.
- Seascape metrics were determined to be useful for investigating implications of habitat quality reduction on fish assemblages in Shark Bay.
- Updated mapping of seagrass extent at Monkey Mia in 2020 suggests some recovery since 2016; maps have now been extended to cover the whole Marine Park for 2022.

**Management implications**

- By identifying and mapping seagrass areas vulnerable to climate stressors, this work will help identify meadows resilient to environmental disturbance that should be protected from other stressors such as dredging.
- An improved understanding of the effects of heat stress on seagrass has been used to develop metrics that can predict the impacts of heat in the future and at other locations.
- Converting habitat maps into seascape metrics provides further detail of the quality of habitat for fish communities, and highlighted the superior value of *Amphibolis antarctica* seagrass meadows (structurally more complex) compared to *Posidonia australis* meadow, which therefore warrants higher conservation focus.

**Future directions**

- Update the Shark Bay seagrass habitat map and quantify change in seagrass extent since 2016.
- Write up results of the assessment of environmental influence on seagrass condition.
- Submit manuscript on fragmentation of seagrass meadows and influence on fish communities in Shark Bay.
- Examine long-term trends in fish assemblages associated with seagrass meadows in Geographe Bay.

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

SP 2014-021

K Waples, H Raudino

**Context**

Australian snubfin (*Orcaella heinsohni*), Australian humpback (*Sousa sahulensis*) and Indo-Pacific bottlenose (*Tursiops aduncus*) 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, opportunistic surveys and anecdotal sightings throughout the region. Although the presence of several coastal dolphin species is expected in nearshore Pilbara waters (including 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 these are key factors 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, leading to greater certainty in assessing and managing impacts related to industrial developments. This project was designed to meet this priority need under the Wheatstone Offset C program.

**Aims**

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

**Progress**

- A paper on minimum image resolution needed to differentiate between small coastal dolphin species from aerial survey was published in a special issue of *Mammalian Biology*.
- Data analyses are complete and a manuscript progressed on using density surface modelling and aerial survey data to better understand abundance and distribution of coastal dolphins at a regional scale in the Pilbara. Abundance estimates are in the low thousands for both Indo-pacific bottlenose dolphin and Australian humpback dolphin, with humpback dolphins apparently less abundant than bottlenose dolphins.

**Management implications**

- A baseline understanding of dolphin distribution and habitat use in the Pilbara region will inform the assessment of environmental impacts relating to future coastal developments and will assist in determining the conservation status of coastal dolphin species in Pilbara waters. The information will be important to inform the Commonwealth review of the conservation status of the humpback dolphin under the EPBC Act.
- The availability of baseline data and long-term monitoring protocols for coastal dolphin species in State waters will inform approaches to conservation and management.

**Future directions**

- Publish manuscript on dolphin abundance and distribution based on aerial survey data for the Pilbara region.
- Undertake genetic analyses of the tissue samples collected from two species of dolphin at the Montebello Islands Marine Park.

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

SP 2014-018

K Waples, H Raudino

**Context**

The lack of knowledge of the Australian snubfin dolphin (*Orcaella heinsohni*) meant that its conservation status could not be adequately assessed in 2011 due to insufficient information on population dynamics and distribution. This species is known from tropical coastal waters of Australia and New Guinea, but individuals tend to be evasive and difficult to study. Although they range southwards to the Pilbara region of Western Australia, there has been little locally based research on this species and the limited data collected remains unpublished. This project will compile existing data on snubfin dolphins across the Kimberley to better understand their habitat use and distribution. The collation of data into a single database will also facilitate the study of population structure and demographics based on recognised individual animals.

**Aims**

- Provide a quantitative abundance estimate of snubfin dolphins for Roebuck Bay in Western Australia that will be used as a baseline for this population component and enable comparison with abundance estimates of the species from sites at Cleveland Bay (Qld) and Port Essington (NT).

- Compare methods for abundance estimation (mark-recapture versus distance sampling) and the suitability of these methods for abundance estimation of this species.
- Map the extent of occurrence and area of occupancy of snubfin dolphins in the Kimberley by combining traditional knowledge and dolphin sightings from Indigenous sea rangers and scientific survey sightings.
- Refine and populate a purpose built and standardised database that will support long term data collection and curation in Western Australia and facilitate data-sharing between jurisdictions.

**Progress**

- The report on the 2022 dolphin census was finalised and shared with joint management partners and other stakeholders.
- A presentation on the collaborative monitoring activity with joint managers was accepted for the Australian Marine Science Association conference.
- The Fin book, containing photo id and individual history information for Roebuck Bay dolphins is being updated.

**Management implications**

- Collation of scientific and traditional knowledge of a poorly understood marine mammal of high conservation value means managers now have baseline knowledge of the abundance of snubfin dolphins in Yawuru Nagulagun Roebuck Bay Marine Park (YNRBMP).
- Establishment of a database for all dolphin research and monitoring where survey and photo-identification data is collected, ensures that standardised data is available for assessing population abundance and distribution. It also provides the capacity to develop sighting histories for individual animals, thus providing a better understanding of population demographics and life history. This database can also be used for information sharing across jurisdictions and between research organisations.
- The broad-scale collation of information and modelling has provided relevant information on area of occupancy and extent of occurrence that can be used to assess the conservation status of snubfin dolphins more accurately.
- The research has established partnerships with Indigenous sea ranger groups to develop survey methodologies, data storage and reporting structures consistent with Healthy Country and reserve management plans.
- The Marine Fauna Sighting app and Finbook photo-identification guide will support ongoing monitoring of the snubfin dolphin population in YNRBMP. They will be used to address the key performance indicators related to maintaining abundance and diversity of dolphin species in YNRBMP.
- A monitoring program for a 3 yearly census of dolphins in YNRBMP will inform ongoing management of dolphins using the marine park and surrounds.
- Understanding the population structure and genetic connectivity of coastal dolphin populations will inform conservation management by identifying populations more vulnerable to anthropogenic impacts.

**Future directions**

- Publish the results of the genetic analyses of tissue samples collected from snubfin dolphins in Prince Regent River.
- Publish a new edition of the Yawuru Nagulagun Roebuck Bay Finbook.

## The influence of macroalgal fields on coral reef fish

SP 2013-006

T Holmes, J Goetze

**Context**

Macroalgae are a prominent component of tropical benthic communities along the north-west coast of Australia. Within Ningaloo Marine Park, large fields of macroalgae are a distinct feature of the lagoon, covering approxi-

mately 2000 hectares. These macroalgal fields are important habitats 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**

- Macroalgal data collected contributed to an Indo-Pacific examination of the broadscale effects of human disturbance on macroalgal cover on coral reefs. The study found that generalisations about total algal cover are ineffective and that finer scale genus level data is required to fully understand ecosystem impacts. A paper was published in *Global Change Biology*.
- Data from fish surveys over the past 11 years were used to examine if abundance of recruit and juvenile fish can predict abundance of adult spangled and yellow tail emperor. Modelling indicates that juveniles reliably forecast abundance of fish 1-2 years of age, but not older fish. A full draft of the paper has now progressed for submission.
- Further information on recruit abundance and macroalgal assemblages was collected.

**Management implications**

- Tropical macroalgal habitats are important nurseries for fish of ecological and fisheries importance in Ningaloo Marine Park. Canopy forming macroalgal fields are therefore, habitats of high conservation value that should be considered for protection when planning marine reserves.
- Identifying locations and environmental conditions that consistently have high abundance and diversity of juvenile fish will help to pinpoint essential nurseries for fish, which as adults play key ecological roles, maintain biodiversity of fish assemblages and/or contribute to local fisheries.
- Understanding how climatic processes affect both the supply of juveniles and quality of nursery habitat improves our understanding of temporal fluctuations in fish abundance and ability to predict future populations.
- Improving the capacity to predict future abundances of adult fishes, particularly those threatened by changes to habitat, climate and fishing pressure, will help to maintain important social values like recreational fishing.
- Understanding the carbon capture potential of benthic communities in marine reserves will better inform future policy and increase our understanding of the broader economic and social value of conserving habitats through marine management practicies.

**Future directions**

- Finalise draft and submit paper analysing the links between juvenile and adult fish abundance.
- Investigate the spatial and temporal dynamics of canopy forming macroalgae at Ningaloo to understand how important macroalgae are for capturing carbon.

# 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 habitat, migration routes and resident foraging grounds. The tracking results identify the geographic range and preferred habitats and provide insight into the viability and survivorship of healthy and rehabilitated turtles in the wild. The identification of preferred habitat allows pressures to be identified and prioritised for different size classes. As tracking results will be broadcast live on the internet (updated daily via www.seaturtle.org) there is a direct link between the department's science activities and the community. The genetic information (derived from samples collected routinely across a range of projects) will provide another layer of information that helps to describe the spatial range of sea turtles in Western Australia.

## Aims

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

## Progress

- A manuscript describing the flatback turtle satellite tracks is in review with *Ecological Applications*. For this study, information from over 300 turtles has been combined from multiple research partners to develop one of the worlds largest animal tracking data sets.
- Additional transmitters were applied to reproductively mature male turtles to fill knowledge gaps on mating areas.
- Movements of tracked turtles were displayed in real time on the sea turtle website (www.seaturtle.org).

## Management implications

- Spatial data of animals is essential to understand movements and habitat requirements of turtles. Data from this project has assisted identification of Biologically Important Areas (BIA) and "habitat critical to survival" including migratory corridors and resident feeding areas of these species that informs conservation planning.
- The tracking studies of flatback turtles in Roebuck Bay has provided insight into habitat use and diet of turtles that can be used for marine park management, including port planning and vessel use.
- Updated information on BIA's and migratory pathways informs management of areas sensitive to human pressures to underpin any management decisions.

## Future directions

- Continue to use a multi-discipline approach of flipper tags, satellite tags, genetics and stable isotopes to understand movements and distribution.

## Marine monitoring program

SP 2012-008

T Holmes, R Evans, W Robbins, C Ross, I Leal, S Strydom, K Murray, S Bell, K Crook, H Raudino, K Carter, J Goetze

### Context

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

### Aims

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

### Progress

- Updated monitoring data was collected by DBCA or collated from collaborators for fish, coral, seagrass, macroalgae, subtidal invertebrates, little penguins, shorebirds, intertidal invertebrates, sea lions, dolphins and water quality during field work conducted across 15 marine reserves from Walpole and Nornalup Inlets Marine Park in the south to North Kimberley Marine Park in the north.
- Updated results and findings from the monitoring program were communicated to Marine Park Coordinators and Regional Managers via the annual Marine Park Performance Assessment process, written advice, and opportunistic presentations. This information included more detailed management advice and data interpretation for the Yawuru Nagulagun/Roebuck Bay, Eighty Mile Beach and North Kimberley marine parks.
- Seven scientific papers incorporating departmental monitoring data or examining developments in monitoring methodologies and indicators were published in *Global Change Biology, Marine Biology, Scientific Reports, Earth System Science Data, Communications Earth & Environment, Estuarine Coastal & Shelf Science* (2 papers),
- Significant progress was made with the development of an online monitoring dashboard application that will eventually replace hard copy reports for individual marine parks. Funding was initially invested into the development of the background workflow, user interface and figure displays for the fish monitoring program across all marine reserves, which is now functional. Additional effort was invested into the development of coral monitoring. The first versions of this were tested with marine park coordinators and used for annual marine park reporting purposes for the first time in June this year.
- Significant scientific advice was provided as a part of the ongoing planning process for Marmion, South Coast and Exmouth Gulf marine parks, through internal planning discussions, risk assessments and management plan revisions, as well as community engagement forums associated with the Marmion and South Coast planning processes.
- Monitoring programs with joint management partners in the Yawuru Nagulagun Roebuck Bay, Bardi Jawi Gaarra and Mayala marine parks were prioritised.

### Management implications

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

### Future directions

- Continue development of the online monitoring dashboard application, particularly in relation to benthic communities (corals, seagrass, macroalgae).
- Continue the implementation and periodic review of ecological value monitoring across the marine reserve system, including planning and prioritising of monitoring activities in the proposed South Coast, Marmion and Exmouth Gulf marine reserves.

## North West Shelf Flatback Turtle Conservation Program

CF 2011-118

S Whiting, S Fossette-Halot, T Tucker

### Context

The Northwest Shelf Flatback Turtle Conservation Program (NWSFTCP) is one of four additional environmental 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. This project coordinates the planning and implementation of works required for the NWSFTCP and coordinates general research and monitoring of marine turtles in Western Australia. The NWSFTCP has a range of governance arrangements that include an advisory committee and a scientific panel.

### Aims

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

### Progress

- The draft synthesis report for the work of the NWSFTCP was progressed.
- Two workshops have been held to start drafting the next strategic plan for the NWSFTCP.
- A manuscript on flatback turtle movements compiling more than 300 satellite tracks has been submitted to *Ecological Applications*.
- Key flatback nesting beaches, including Delambre and Thevenard Islands, Port Hedland, Eco Beach, Cable Beach and Cape Domett, continued to be monitored. Community events have been organised in Port Hedland and Broome to share the main results from the monitoring programs with volunteers, local staff and traditional owners.
- Indigenous engagement activities continued at several sites including employment at Delambre Island, community visits at Thevenard and Delambre Islands and involvement in a collaborative project with Yawuru traditional owners.
- A Traditional Custodian Collaboration Strategy and a Communication Strategy for the NWSFCTP have been drafted and are in their final reviewing stages before being published.
- The three PhD students co-supervised by NWSFTCP staff have all submitted their PhD theses and successfully defended them, with one receiving an honourable mention on the Dean's list.

### Management implications

- Sea turtle monitoring requires long term data sets. The foundations are established for a robust monitoring program for the North West Shelf genetic stock of turtles to inform conservation and management decisions.
- The flatback turtles foraging project at Roebuck Bay provides insight into biology and ecology of resident flatbacks and provides access to turtles for health studies. It has provided a spatial context to habitat use that can be used by joint managers (DBCA and Yawuru Aboriginal Corporation) to assess how other activities in the bay such as pearling, shipping and recreational boating overlap with flatback turtles.
- Culling foxes at Mundabullanagana Station contributes to protection of turtles by directly mitigating mortality of eggs and hatchlings.
- Partnerships with Pilbara and Kimberley Indigenous groups enhance the long-term benefits of the program by providing a cultural perspective and relevance to the work; positive communication of the program throughout the communities, stability in governance and advice pathways, and a way of transferring information.

### Future directions

- Finalise the synthesis report and the strategic plan.
- Continue to monitor key flatback nesting beaches including Delambre and Thevenard Islands, Port Hedland, Eco Beach and Cape Domett. Analyse long-term datasets and write up reports.
- Build and maintain Indigenous partnerships, engagement and employment through local opportunities and training.

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

SP 2009-013

I Leal

### Context

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

### Aims

- Determine spatial patterns and temporal variation in the WNIMP benthic invertebrate community.
- Assist in developing long-term monitoring methods for benthic invertebrates in WNIMP and more broadly across temperate estuarine marine protected areas.
- Determine whether there are spatial and temporal differences in fish community structure (species composition, abundance, age class) in WNIMP.

### Progress

- Collaborated with Edith Cowan University (ECU) for the student camp at WNIMP to collect data on bivalve, gastropod and polychaete communities.

- Polychaete samples are being processed to generate a second year of data for analysis in collaboration with ECU and the WA Museum.
- Completed a manuscript on environmental drivers of diversity and abundance of infaunal assemblages in the Walpole and Nornalup Inlets Marine Parkfor submission to *Estuarine, Coastal and Shelf Science.*

**Management implications**

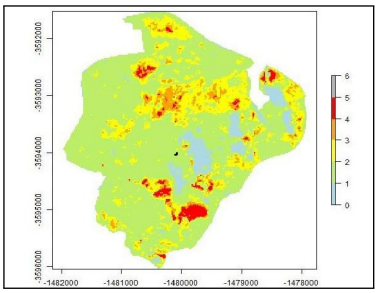
- Knowledge of spatial and temporal patterns of benthic invertebrate distribution is important for understanding the condition of this community in relation to the influence of natural processes and possible anthropogenic impacts. The study will assist in the implementation of long-term benthic invertebrate community monitoring of this Key Performance Indicator for the WNIMP.

**Future directions**

- Use the current dataset to establish long-term monitoring sites and determine indicator species in the infaunal assemblages.
- Analyse multiple data sets and prepare reports and manuscripts for publication.

# Fire Science

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




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

SP 2018-134

V Densmore, K Zdunic

### Context

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

### Aims

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

**Progress**

- Severity mapping has progressed to become business-as-usual practice in DBCA, utilising corporate records for all new burns within the State's south-west on a monthly basis during spring and autumn. Maps are provided to relevant districts and uploaded into the corporate dataset
- Over 1500 historical severity maps across 106 forest blocks within the Northern Jarrah IBRA have been processed, and work is underway to update DBCA's fire history records and the public-facing DBCA-60 dataset with the verified extent and dates of burns and fires occurring since 1988.
- Work is well-progressed to provide severity maps via a spatial indexthat contains all the burn shapes mapped linked to both imagery and data. R-scripting underlying this process is being developed, with the intention it will be extended to the DBCA toolset.
- A paper describing OzCBI (the field-truthing method) and the modelling process has been published in *Australian Forestry*.
- A paper using historical severity maps within the Upper Warren Catchment to investigate the role of severity in affecting populations of four threatened mammal species has been published in *Global Change Biology*.
- A paper detailing habitat outcomes over two years relative to severity in south-west forests is in preparation.

**Management implications**

- Improved understanding of how severity classes relate to habitat retention and future fire risk will inform adaptive management of fire, priority species and ecological communities, and contribute to refinement of the prescribed fire planning process, including development of objectives that are measurable, achievable and relevant to particular land management values.
- Routine and standardised severity mapping will support cost-effective and meaningful reporting on the extent to which prescribed burning has achieved specified objectives and success criteria for biodiversity management, bushfire risk management and other land management values, including forest regeneration.
- Analysis of historical fire severity and the relationship between aerial ignition patterns and fire severity will support identification of key drivers of fire outcomes across vegetation types and regions and an informed comparison of the effectiveness of the overall fire management program.

**Future directions**

- This project will be completed with finalisation of paper on habitat outcomes.

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

SP 2018-046

B Miller, R Miller

**Context**

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

### Aims

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

### Progress

- Weed management was continued at the Kings Park, Bold Park and Yangebup sites.
- Comprehensive floristic and fuels surveys were conducted at all sites, including a post-fire survey at the Kings Park site following an experimental burn in May 2022.
- Analysis of floristic patterns in response to burn and weed management treatments is well underway and being prepared for publication.
- A refined allometric relationship for grass fuel loads was developed.
- Site visits were held with local community and university student groups to share findings and demonstrate management implications.

### Management implications

- Identification of optimal combinations of weed and fire management treatments will provide a basis for recommendations for the management of peri-urban and urban bushlands.
- Burning without weed management results in increased grass weed cover and poor recovery of native species.
- Post-burn weed management is effective in maintaining low levels of weed cover at pre-burn levels (or lower) and beneficial for native community regeneration.

### Future directions

- Ongoing implementation of weed management treatments and floristic and fuel surveys in all sites.
- Undertake experimental burn in the Bold Park site.
- Complete analysis of floristic response to burn and weed treatments across all sites.
- Completion of analyses for Kings Park and Bold Park sites and submission of fuel, vegetation structure and composition and weed cover analyses manuscripts for publication.

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

SP 2012-029

V Densmore, S Samson

### 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 essential for developing and implementing ecologically appropriate fire regimes and managing fire to reduce risk to the community, biodiversity and other environmental values.

### Aims

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

### Progress

- Site visit to McCorkhill (Jalbarragup) was undertaken with Wadandi elders as traditional custodians to discuss fire effects and potential differences if cultural burning were undertaken.

- Consideration is being given to incorporating cultural burning as an additional regime at two plots within the McCorkhill site.
- A paper utilising data from this study in a global comparison of fire effects was published in *Ecology Letters*.
- Materials have been acquired to add fencing to the McCorkhill plots to align their experimental design (herbivore exclusion) to the Perup plots

**Management implications**

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

**Future directions**

- Undertake fuel structure and floristic surveys at McCorkhill and Perup plots.
- Maintain the integrity of study sites for ongoing monitoring in the longer term, including continuing current burn regimes.

## North Kimberley Landscape Conservation Initiative: monitoring and evaluation

SP 2012-027

I Radford

**Context**

This project is a biodiversity monitoring and evaluation program to inform adaptive management of fire and cattle in the north Kimberley. The adaptive management program that forms the Landscape Conservation Initiative (LCI) of the *Kimberley Science and Conservation Strategy* commenced in 2011 in response to perceived threats by cattle and fire to biodiversity conservation in the North Kimberley. This initiative is based on the hypothesis that large numbers of introduced herbivores and the impacts of current fire regimes are associated with declines of critical weight range mammals, contraction and degradation of rainforest patches, and degradation of vegetation structure and habitat condition in savannas. This monitoring and evaluation program will provide a report card on performance of landscape management initiatives in the north Kimberley, particularly prescribed burning and cattle culling, in maintaining and improving biodiversity status.

**Aims**

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

**Progress**

- Trapping at Mt Hart, Wunaamin Miliwundi National Park, Mt Trafalgar and Prince Regent National Park, shows that northern quolls persist following cane toad invasion. Individuals were captured in both locations following years where none were captured.

- Increasing the areas of longer unburnt vegetation using patch mosaic burning has contributed to re-establishment of *Rattus tunneyi* populations in the Mt Trafalgar area. This species disappeared after extensive fires in 2016, but was re-trapped in 2023 monitoring. This result vindicates ongoing evidence-based development of the Kimberley fire management program.
- Monitoring continues to inform on threatened mammal fire responses, showing that some species, including golden-backed tree-rats and other rodents, may have peak abundance at 4-6 years post fire, followed by population decline.
- Analysis of vegetation change under a decade of fire management indicates savanna structural stability under adaptive management and climate change.
- An experiment assessing the potential synergies among fire and weed management for invasive annual grader grass (*Themeda quadrivalvis*) was established in Wunaamin Conservation Reserve with prefire plant community composition and cover assessed both prior to and after treatment. Treatments involved combinations of fire and either no herbicide or one of two herbicide treatments. Sites were assessed in collaboration with East Kimberley District officers and Bunuba Rangers.

**Management implications**

- Analysis of the monitoring data shows that increasing patchy early dry season prescribed burning benefits most threatened species.
- The fire mosaic attribute most closely aligned with high diversity and abundance of threatened mammals is percentage of long unburnt vegetation. This indicates that long unburnt patches are an important target for prescribed burning in the region.
- There is now strong evidence that cattle have a negative influence on threatened mammals such as the brush-tailed rabbit rat. This supports continuation of the department's feral cattle culling program for the benefit of threatened mammals and the other groups threatened by cattle.
- Feral cats are strongly negatively associated with threatened mammal abundance and richness. In this context, it is important to maintain vegetation cover through fire and cattle management to reduce cat hunting effectiveness.

**Future directions**

- Continue monitoring to evaluate management effectiveness for threatened mammals and other groups across the Kimberley region.
- Undertake occupancy modelling to determine the response of threatened species to fire regimes and other threatening processes.
- Undertake analysis of change in vegetation condition under prescribed management regimes.
- Follow up survey and second treatments in grader grass experiments.

## Fire regimes and impacts in transitional woodlands and shrublands

SP 2010-011

C Gosper

**Context**

The Great Western Woodlands (GWW) is an internationally significant area with great biological and cultural richness. This 16 million hectare region of south-western Australia contains the world's largest and most intact area of contiguous temperate woodland. The GWW Conservation Strategy and a review conducted by a wide range of scientific experts identified inappropriate fire regimes as a threat to the woodlands and emphasised the need for a science-based fire management regime for the area. Critical gaps in the knowledge of fire ecology for GWW ecosystems are a hindrance to ecological fire management in the region. The GWW supports eucalypt woodlands at very low mean annual rainfall (250-350 mm). Many of the woodland eucalypt species are killed by fire (obligate-seeders), and eucalypt recruitment is stimulated by fire but individuals are slow growing. In recent decades a large part of the GWW has been burnt and concern has been expressed over the ecological

impacts of this. Fire ecology research already undertaken in eastern Wheatbelt nature reserves will help resolve ecological fire management issues for mallee and mallee-heath communities in the GWW but similar information for the dominant eucalypt woodlands is needed.

**Aims**

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

**Progress**

- Analysed combined on-ground vegetation structure measurements of tree allometry with high-resolution remotely piloted aircraft and medium-resolution airborne LiDAR and coarse-resolution GEDI satellite LiDAR covering the whole region. This analysis demonstrated that woodland age classes can be reliably distinguished based on their 3D canopy structure and supported identification of vegetation structural features that scale robustly across platforms for development of a spatial model of woodland age class across the whole GWW. A paper on this work has been submitted for publication.
- Vegetation structure and biomass data from the *E. salubris* chronosequence was used to calculate changes in woodland carbon stocks with time since fire, in collaboration with CSIRO Environment and supported by Woodside Energy.
- Juvenile period data from the *E. salubris* chronosequence formed part of a south-western Australia-wide analysis showing that juvenile period in slow-maturing serotinous obligate seeders can be predicted from climate and site productivity, allowing the development of models of juvenile period over space and time under both recent environmental conditions and those projected to occur in the future. The spatial data from this work have been made available through the Corporate Data Delivery Program and DataWA, and a BCS Information Sheet was produced to inform on-ground fire management.
- Plant trait data from the *E. salubris* chronosequence underpinned staff involvement in national seed and dispersal trait and fire response and regeneration trait workshops hosted by the AusTraits collaboration. This work has led to the compilation of the AusTraits Plant Dictionary, which provides a clear scope and description of over 500 plant traits, with this resource available online and submitted for publication.

**Management implications**

- National-scale syntheses of temperate eucalypt woodland responses to disturbance revealed that many Western Australian woodlands are uniquely dominated by taxa that are obligate seeding, and have vegetation dynamics driven by rare, stand-replacing disturbances. These characteristics illustrate a putative vulnerability to decreases in intervals between fires, and large changes in vegetation composition, structure and carbon stocks with time since fire and with variation in prior fire interval. This information contributes to understanding ecological and functional responses to fire.
- Post-fire succession in vegetation composition and structure, which in turn determines successional patterns in animals, occurs over multi-century timescales, demonstrating the value of avoiding fire in mature woodlands to maximise future fire management options.
- Development of spatial and temporal models of juvenile period in slow-maturing serotinous obligate seeders across south-western Australia allows identification of where: (i) historic fire intervals may have led to immaturity risk impacts, assisting in delineation of areas and taxa for which targeted conservation interventions may be most valuable; and (ii) the risks of climate change-driven decreases in fire intervals are greatest and where fire management to support persistence of fire refugia is most important.
- A spatial map of multi-century GWW woodland age classes provides the basis for departmental, Department of Fire and Emergency Services and Ngadju Conservation Aboriginal Corporation fire managers to plan fire mitigation and suppression activities to minimise loss of mature woodlands in bushfires.

### Future directions

- Finalise journal publications on changes in carbon stocks with time since fire and the eucalypt woodland age class distribution.
- Develop a carbon accounting method in GWW eucalypt woodlands accounting for carbon fluxes with fire and woodland growth.

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

SP 2004-004

A Wills

### Context

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

### Aims

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

### Progress

- A manuscript describing the effects of mosaics and vegetation on epigaeic invertebrate richness and trophic structure has been drafted.
- A draft manuscript describing the effects of mosaics on vegetation has been prepared.
- A manuscript describing interaction between rainfall and fire intensity effects on fungi fruiting body diversity has been drafted.
- An overview manuscript on effects of mosaic fire versus wildfire on plant, fungi and epigaeic macroinvertebrate biodiversity has been submitted.
- A manuscript on beetle richness responses to time since fire has been submitted.

### Management implications

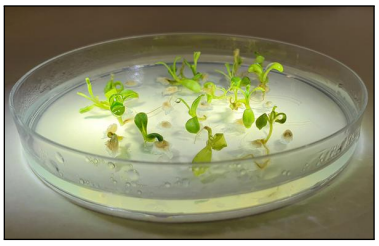
- This study demonstrates that fine-grain patch-burning is operationally feasible in forest areas. Although data analysis is incomplete, benefits to biodiversity at the landscape scale, especially cryptogams, invertebrates, fungi, and birds through retention of patches of a range of vegetation ages are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

### Future directions

- Complete publication on epigaeic invertebrate richness, overview paper covering the biodiversity outcomes of mosaic burning, and beetle richness with time since fire.

# Kings Park Science

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



## Seed science

SP 2018-085

D Merritt

### Context

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

### Aims

- Support and enhance the curation of *ex situ* collections of germplasm through resolving seed storage behaviour and longevity, developing methods for assessing seed quality and predicting seed storage life.
- Develop reliable methods for seed-based propagation through determining seed dormancy break and germination requirements.
- Develop seed enhancement technologies that improve seedling establishment for broad-scale restoration.
- Engineer efficient mechanised broad-scale delivery of diverse seed types to restoration sites, including sloped and rocky landforms.

- Inform the management of Western Australia's flora through the study of seed ecology in the natural environment.

**Progress**

- Initiated experiments comparing seed ageing in open vs hermetic storage conditions to quantify the differential effect of oxygen across different species.
- Commenced experiments to examine the utility of RNA integrity as a predictive measure of seed viability decline in storage.
- Contributed to a national review of Australian plant species that are not suited to conventional seed banking practices to highlight pathways for alternative methods of *ex situ* conservation.
- Commenced a five-year project to continue development of seed enhancement technologies and direct seeding machinery for broad-scale rehabilitation.
- Completed a study quantifying seedling life-stage transitions in reconstructed mine soils across differing levels of simulated rainfall to inform seeding practices.
- Contributed to delivery of the Australian Virtual Seed Bank, providing open access to seed collections data of the Australian Seed Bank Partnership.

**Management implications**

- Knowledge of seed biology contributed to development of an *Ex Situ* Conservation Strategy that provides a framework for resourcing, managing, and developing BGPA's collections and associated data into the future.
- A national review of plant species that are difficult to collect, bank and utilise, has provided a workflow to identify additional exceptional species to direct efforts towards establishing alternative germplasm conservation methods including tissue culture and cryopreservation, and identified research priorities to improve curation and use of germplasm for conservation.
- Development of future seeding technologies and seed enhancements will improve the moisture relations of the microsite to increase the chances of seedling recruitment in altered growing substrates, such as overburden mine wastes.

**Future directions**

- Continue to develop techniques for modelling seed longevity to identify short-lived seeds, assess RNA integrity and assess respirometry data.
- Monitor experiments focused on identifying alternative storage protocols for short-lived seeds.
- Assess emergence capabilities of seedlings through rocky soil profiles.
- Apply and assess new seed enhancement strategies and combinations of treatments , for diverse species required for rehabilitation.
- Continue to focus on resolving seed dormancy and developing reliable seed propagation techniques for priority species for conservation, translocation, and restoration.

## Restoration science

SP 2018-077

J Stevens, S Krauss, W Lewandrowski, C Elliott

**Context**

Restoration science is a multidisciplinary approach to provide a comprehensive scientific basis for restoration actions across the State. Overall, the research includes seed science, provenance, ecohydrology, ecophysiology, soil science, community ecology and plant-enabling technologies. Restoration science works across diverse systems including Pilbara grassland and savanna, mid-west shrublands, Swan Coastal Plain banksia woodlands

and shrublands, jarrah forest, marine seagrass meadows, and arid coastal communities, through collaboration with a variety of stakeholders. Restoration science is well placed to provide the applied scientific solutions required for all plant community restoration activities.

**Aims**

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

**Progress**

- Continued to use ecophysiological and remote sensing tools to monitor chlorotic decline syndrome within the jarrah and marri trees of Kings Park. This data is supporting baseline observations before mitigation actions (acidifying the bore water) are undertaken in Kings Park in late 2023.
- Extended the collaborative program with Department of Primary Industries and Regional Development to understand biodiversity values of Kimberley grassland grazing systems. Small scale plots were established in Perth to determine seedfarming constraints for priority grasses. Exclosure plots that were previously established in the Kimberely have been assessed to understand constraints to native grass seedling establishment.
- Continued to optimise habitat modelling approaches for the narrow range endemic *Aluta quadrata* from the Pilbara and have undertaken ecophysiological surveying, isotopic and mineral nutrition studies to understand plant niche requirements.
- Commenced a project to study the pollination and reproduction of the endangered *Aluta quadrata* in the Pilbara.
- Commenced initial species distribution modelling for the rare ironstone endemic *Tetratheca butcheriana* from the Pilbara to inform niche suitability and site selection for ecophysiological monitoring of the rock endemic.
- Contributed to several projects through CRC TiME (Transformations in Mining Economies), including: studying the effectiveness of climate-adapted seed sourcing strategies for revegetation success and transition to mine closure in a changing climate, The Australian Seed Scaling Initiative and Returning Ecosystem Resilience.
- Continued field and controlled environmental studies for *Stylidium* species to determine climate and edaphic interactions on seed biology and plant ecophysiology in the jarrah forest along the Darling Scarp.

**Management implications**

- Providing baseline physiological and tree canopy information of jarrah and marri trees currently impacted by chlorotic decline will enable quantifiable impacts of changing irrigation infrastructure and regimes on tree health.
- Providing findings from rare species distribution models, plant function and interactions with pollinators informs decision making around rare species conservation and management within the mining sector.
- Informing seed sourcing and seed usage to deliver greater biodiversity in a more cost-effective manner to support minesite rehabilitation programs.

**Future directions**

- Continue to develop an understanding of drivers of rare species functioning and distributions to inform conservation and restoration strategies.
- Continue to determine seed biology, ecology, pasture values and seed production capability of northern native grass species to inform potential management of the Kimberley rangeland systems.
- Continue to revolutionise the way seeds of native species are collected and used in rehabilitation to ensure resilience and biodiverse outcomes for a range of stakeholders.

## Conservation genetics

SP 2018-068

S Krauss, E Sinclair, J Anthony

### Context

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

### Aims

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

### Progress

- Continued monitoring of large scale multi-species provenance trials established with 32,000 seed at 8 sites across the Swan Coastal Plain.
- Seed germination experiments were completed to demonstrate provenance effects of temperature, moisture and drought on germination.
- Pollinator exclusion experiments were continued with multiple species to examine the relative effectiveness of honeypossums, birds and insects as pollinators.
- *In situ* field trial established in Shark Bay to assess the benefits of polyploid seagrass over diploids for ecological restoration.
- Engaged with traditional owners in Shark Bay for two-way integration of western science and Indigenous knowledge for seagrass meadow restoration.
- Opportunities and challenges for microbiomics in ecological restoration were assessed.
- Multiple study populations were established and fruit harvested for mating system and pollination biology studies on *Aluta quadrata*.

### Management implications

- Complete early seedling death in some provenance trial sites highlight the critical importance of substrate reconstruction for restoration of highly disturbed sites.
- Polyploid seagrass in Shark Bay may be better for seagrass meadow restoration than its diploid progenitors.
- Microbiomics has great potential to advance our understanding of complex plant-soil microbial processes and interaction networks, which can be applied to improve ecosystem restoration.
- Ecological genetic analysis can assess impacts from mining on rare species.

### Future directions

- Assess and publish results of large-scale provenance trials, glasshouse trials, and seed germination trials for key species from banksia woodlands.
- Assess and publish results of reciprocal transplant trials with polyploid and diploid seagrass in Shark Bay.
- Conduct experimental molecular and ecological studies of pollination by birds and mammals on banksias.
- Establish multi-species provenance trials in the northern Jarrah Forest and Pilbara for an assessment of climate adjusted seed sourcing strategies for ecological restoration.

- Commence a multi-year study on the genetic and biochemical basis for flower colour in kangaroo paws.
- Continue a multi-year study on the pollination biology of *Aluta quadrata.*

## Orchid conservation and recovery

SP 2018-060

B Davis, J Stevens

### Context

Western Australia is an orchid biodiversity hotspot of worldwide significance, with 413 named species of orchid, of which 95% are endemic. There are currently 44 Western Australia orchid taxa listed as threatened, with the key threatening processes being habitat loss due to land clearance and fragmentation, loss of pollinators, weed invasion, illegal collection and habitat degradation. Orchids represent a conservation challenge as they have complex and sometimes highly specific ecological interactions with pollinators above ground and their mycorrhizal partners below ground. Overlaying the immediate needs of the orchid are the independent requirements of the pollinator (nectar sources, brood sites) and the mycorrhizal partner (carbon sources, soil attributes). *Ex situ* conservation of Western Australia's orchids is undertaken through maintaining a large living collection of orchids, seed banking and maintaining an orchid mycorrhizal library. Scientific research into pollination, orchid ecology, translocation, propagation and mycorrhizal function underpins successful species recovery in the Orchidaceae.

### Aims

- Determine and prioritise those orchid species most at threat and undertake *ex situ* conservation actions leading to supplementation of natural populations, to ensure their ongoing persistence.
- Continue maintenance and growth of the *ex situ* living collection, seed and fungal collections.
- Conduct integrated conservation research to provide management solutions to improve the conservation status of threatened orchid taxa.
- Make collections of seed and fungi from threatened and priority listed species to investigate the potential for supplementation of wild populations.
- Maintain and build *ex situ* seed and fungal banks of the orchid flora of Western Australia for conservation and research purposes.

### Progress

- The third phase of the *Caladenia busselliana* translocation was undertaken with 216 dormant tubers planted at a historic population site. Monitoring of previous translocation plantings for survival, growth and reproductive success has been ongoing.
- A further 600 *Caladenia viridescens* were propagated and successfully transferred to the glasshouse as stock for planned translocations and an *in situ* seed orchard.
- Successful germination protocol established for *Pterostylis sinuata*, a species previously unable to be grown successfully.
- Transfer of seedlings to the living collection resulting from ex situ collections of threatened orchids of the Midwest, involving a total of 2060 plants across six species, representing the geographic range of each species.
- Expanded regional pollinator surveys for *C. busselliana* to help inform future translocations.
- Two potential translocation sites were identified for *Caladenia lodgeana* based on pollinator presence, site tenure and management security.
- Surveys across the extent of *C. lodgeana, C. viridescens* and *C. busselliana* provided updated numbers on population size and new plants.
- Long term demographic monitoring to improve population viability analysis was completed for *Caladenia leucochila* and *C. lodgeana*.

### Management implications

- Development of germination protocols for threatened orchid species provides conservation support in the form of *ex situ* living collections, advances the possibility of translocations as a conservation tool and informs *ex situ* collection practices for functionally similar species.
- Growing *ex situ* collections of threatened orchids provides essential conservation support for species with critically low wild plant numbers or single populations. The provision of plant material to undertake pollinator research and site selection for translocations is critical to species recovery efforts.
- Pollinator identification, pollination syndrome, abundance of pollinators and distribution across habitat types inform regional conservation management of habitat remnants, selection of potential translocation sites and whether reproductive management of the orchid species may be necessary.
- Updated population numbers, the discovery of new plants and populations of threatened orchid species provides vital data to regional managers to better manage populations of these threatened orchids.
- Long term demographic monitoring data for orchids is rare but vital to perform population viability analysis and provide an understanding of orchid life stages, recruitment, reproduction and life span to inform species management and recovery.

### Future directions

- Undertake research to inform regional planning and management of threatened and conservation listed orchid species.
- Make targeted seed and fungal collections to supplement *ex situ* orchid collections .
- Investigate orchid, pollinator and mycorrhizal ecology as it relates to species recovery efforts and *in situ* management of populations.
- Optimise propagation protocols across orchid genera to increase supplementation success from laboratory to *in situ* sites.

## Conservation biotechnology

SP 2018-048

E Bunn, B Funnekotter

### Context

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

### Aims

- Develop micropropagation for plants requiring translocation and for living collections.
- Develop cryopreservation protocols for *ex situ* long-term storage of germplasm of selected species.

### Progress

- Research is continuing on cryogenic approaches to conserving species affected by myrtle rust.
- Novel cryoprotective agents were assessed for thermal characteristics and toxicity to plant germplasm for cryostorage.
- A novel pH indicator mixture was developed for monitoring performance of tissue culture medium across multiple species.

**Management implications**

- *In vitro* propagation provides *ex situ* germplasm material for threatened species where cutting propagation or seed is unavailable. This approach provides biosecure storage in culture collections or cool storage for selected genetic material of endangered plants. This material can be accessed to provide plants for future translocations if required.
- Cryopreservation provides very long-term biosecure storage of shoot tips, protocorms, seeds and other material of threatened plant species, that can also be revived and utilised to produce plants for restoration purposes.

**Future directions**

- Audit the *in vitro* collection the assess relevance, purpose and completeness in regards to the new BGPA Ex-situ Conservation Strategy.
- Continue research to understand the effects of cryopreservation on the metabolism of plant germplasm.
- Develop transcriptomic methods to assess stress response in plant material during cryopreservation.
- Develop *in vitro* propagation for new species of threatened Australian plants.
- Develop cryopreservation protocols for species that may possess recalcitrant seeds and/or may be threatened by myrtle rust in the future.

# Perth Zoo Science

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

## Western ground parrot husbandry

SP 2018-137

A Ferguson

### Context

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

### Aims

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

### Progress

- Research continued to further understand the reproductive biology and ecology of the species, including captive and field studies.
- A female laid four eggs in 2022 after the pair exhibited positive courtship behaviour and multiple copulations, but none hatched. It appeared that at least one egg was fertile.

- Planning for a possible artificial insemination attempt began with researchers in Germany.
- Plant material was collected from field sites for stable isotope analysis to test a technique which, if successful, will allow a comparison between captive and wild diets.
- The feasibility of micro CT scanning to measure bone density was tested at the Harry Perkins Institute to assess whether the bone densities of recently captured wild birds are within the historically expected range.
- Camera data from the 2022 breeding season was analysed.

**Management implications**

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

**Future directions**

- Continue to attempt to breed in captivity, including possible trials using artificial insemination.
- Use stable isotope analysis to understand differences between wild and captive diets.
- Use bone density scanning technology available through partnerships to better understand the health of the birds.

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

CF 2018-119

C Holland, S Neate, E Polla

**Context**

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

**Aims**

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

**Progress**

- The bull elephant has completed olfactory trials, with results demonstrating that elephants are capable of very accurate memory recall and specific scent identification.
- Statistical analysis of the bull elephant data was conducted and a manuscript is in preparation.
- Data collection for the cow elephant trial continued.

### Management implications

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

### Future directions

- Complete the trials and analyse the results.

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

CF 2018-118

C Holland, E Polla

### Context

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

### Aims

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

### Progress

- The cognitive repeat behaviour trials have been completed. The 'Mark' cue is currently being attached to additional selected behaviours.
- Training continues with good results and memory recall, clearly demonstrating the excellent memory and ability to discriminate in Asian Elephants.

### Management implications

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

### Future directions

- Complete data analysis and publish results.

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

SP 2018-115

E Polla

## Context

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

## Aims

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

## Progress

- Animal interactions have been monitored in the mixed species billabong exhibit, including the interactions between turtles, lizards and fish.
- The way macropods interact with exhibit access points has been recorded.
- Female Baudin's cockatoos have been observed to monitor general behaviour and food choice in relation to beak growth.
- Monitoring of elephant behaviour via CCTV provided insight into their nocturnal behaviour.
- Observations were conducted for both the tiger and lions.
- CCTV review of the estuarine crocodile allowed us to better understand his activity patterns.

## Management implications

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

## Future directions

- Analyse data from the welfare reviews and compare with other zoos in the region.
- Provide empirical data to support accreditation process for a broader range of species.

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

SP 2018-102

H Mills

### Context

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

### Aims

- Breed and rear white-bellied and orange-bellied frogs for release to sites to maintain or increase the current extent and viability of populations of these species.

### Progress

- A captive breeding colony of *A. alba* and *A. vitellina* was maintained.
- Egg clutches of both species were collected from the wild (8 nests of *A. alba* and 5 nests of *A. viteliina*)
- Metamorphs were raised to 11 months of age, at which point they were released to the wild.
- 107 *A. alba* and 40 *A. vitellina* juveniles were each released into sites in conservation estate east of Margaret River.

### Management implications

- Captive bred and reared frogs have provided the best, and in most cases, the only means of increasing the number of individuals in a subpopulation, and bolstering the genetics of isolated populations.

### Future directions

- Harvest *A. alba* egg nests from the wild and continue rearing and captive breeding.
- Pause collection of *A. vitellina* egg nests in 2023 while new release sites are identified.

## Western swamp tortoise breed for release program

SP 2018-101

H Mills

### Context

Western swamp tortoises (*Pseudemydura umbrina*) are listed as critically endangered and occur in only two natural populations at very low numbers. Establishing new populations entirely with wild caught tortoises is not feasible and captive breeding provides a source of animals for supplementation of wild populations and establishment of new populations. Captive bred tortoises have enabled new populations to be established at Moore River Nature Reserve and Mogumber Nature Reserve, with trial assisted colonisation sites on the south

coast of Western Australia. Two additional captive insurance populations have been established at Adelaide Zoo and Monarto Zoo (South Australia) to reduce the risks associated with keeping half the global population of western swamp tortoises in a single facility.

**Aims**

- Produce a minimum of 30 hatchling tortoises (> 30 days of age) each year for release into wild sites.

**Progress**

- Forty-four juvenile tortoises were released into two swamps east of Augusta in spring 2022 as part of a planned conservation introduction.
- A further 147 hatchling and juvenile tortoises were released to Moore River Nature Reserve.
- Forty-seven hatchlings were produced from a combination of artificially incubated eggs and those left in ground nests.

**Management implications**

- The trial of naturally incubating eggs in ground nests did produce hatchlings and further work is necessary to determine whether to adjust husbandry procedures to maximise the fitness of animals for release to the wild.
- Understanding the cues to hatching will inform decisions on the management of both wild and captive populations.

**Future directions**

- Continue to produce juvenile animals for release to sites.
- Research the breeding ecology of western swamp tortoises using wild and captive populations.

## Dibbler breed for release program

SP 2018-099

H Mills

**Context**

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

**Aims**

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

**Progress**

- Forty-four dibblers were released onto Dirk Hartog Island National Park in spring 2022, bringing the total number released onto the island to 136.

- Six dibblers were brought into the zoo from Escape Island to supplement the genetic integrity of the program and facilitate further breeding.
- Forty-nine pouch young have been born in 2023.
- Planning is underway for the final release of captive-bred dibblers to Dirk Hartog Island National Park in spring 2023, after which the captive breeding program will be completed.

**Management implications**

- The reintroduction of dibblers onto Dirk Hartog Island National Park will exceed the target of 150 individuals, increasing the likelihood that translocated animals will form a sustainable and genetically viable breeding population on the island.

**Future directions**

- This project is complete.

## Numbat breed for release program

SP 2018-098

H Mills

**Context**

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

**Aims**

- Produce yearling numbats in sufficient quantity to support proposed reintroductions to wild sites.

**Progress**

- Twelve juvenile numbats were produced in 2022.
- Eleven numbats were released into a fenced enclosure in Mallee Cliffs National Park, NSW.
- One sub-adult female numbat was released into a fenced enclosure in Secret Rocks Mallee Refuge, South Australia.
- Four numbats were brought into the program from Dryandra National Park to expand the genetic integrity of the breeding program.
- 14 pouch young were produced in the 2023 breeding season.

**Management implications**

- Breeding of numbats provides animals to supplement existing populations and establish new populations across the former range of the species, enhancing populations' genetic diversity and viability.

**Future directions**

- Continue to produce numbats through captive breeding to meet demand from approved translocation programs.

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

SP 2018-025

H Mills

## Context

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

## Aims

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

## Progress

- Banding was undertaken for 131 (103 as pullus, 4 as adults and 24 rehabilitated) Carnaby's cockatoos, along with 8 Baudin's cockatoos (all rehabilitated) and 21 forest red-tailed black cockatoos (all rehabilitated).
- 36 recovery records and re-sightings (photo identification or scanning of microchips) were made of Carnaby's cockatoos and two Forest red-tailed black cockatoos. Only five of those records involved birds that had died – one that died in the nest hollow as a pullus and three that died due to misadventure, major traumatic events or of unknown cause(s).
- Three research papers have been submitted for review or have been revised and re-submitted. One paper focuses on whether conservation management of Carnaby's cockatoo should be considered at a regional level; one focuses on the use of accelerometry to reveal foraging on a novel food source to reduce energetic costs of nestling provisioning in Carnaby's cockatoo; and, one reports on the health parameters of wild Carnaby's cockatoo nestlings.
- Analyses of banding data for Carnaby's cockatoo to determine a more accurate annual survival estimate continued, along with annual survival estimates for rehabilitated Carnaby's and forest red-tailed black cockatoos.
- Work continued on a manuscript describing the costs of rehabilitating black cockatoos, relative to other types of conservation action.

## Management implications

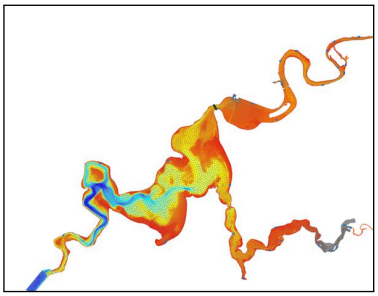
- This project has seen the successful release of 757 leg-banded rehabilitated cockatoos (418 Carnaby's, 53 Baudin's and 286 forest red-tailed black cockatoos). The total number of cockatoos banded (all species and all ages) is now 2087 providing data for understanding breeding dynamics of the population. The rehabilitation techniques and release protocols currently in use provide very high survival rates, as supported by the high number of cockatoos which contributes to the conservation of these three species.

## Future directions

- This project is complete.

# Rivers and Estuaries Science

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



## Using Swan Canning Estuarine Response Model to optimise oxygenation plant efficiency

SP 2022-034

S Adiyanti, K Trayler

### Context

Understanding spatiotemporal variability in hydrodynamic and biogeochemical conditions of the Swan Canning Estuary is essential to improve the distribution of oxygen-saturated water injected via side-stream supersaturation oxygenation plants at Guildford and Caversham. Information on dissolved oxygen distribution and likelihood of benthic water experiencing hypoxia in each season are needed to ensure the plants are operating optimally under current and future climate conditions. This project will contribute to improved oxygenation approaches in the estuary by developing better understanding of variability and drivers of oxygen conditions and enabling predictive support for decisions in relation to oxygenation effectiveness.

### Aims

- Refine the application of a 3D hydrodynamic oxygen predictive model, the Swan Canning Estuarine Response Model (SCERM44).
- Understand the impact of seasonal variations of the estuary conditions on the extent of the oxygenation plant generated plumes.
- Understand how salt wedge dynamics influence oxygen distribution.
- Understand the influence of the catchment inflow water quantity and quality.
- Assess approaches to improve oxygenation plant efficiency.

- Assess the potential impact of 2030 climate change scenario and oxygenation adaptation required.

**Progress**

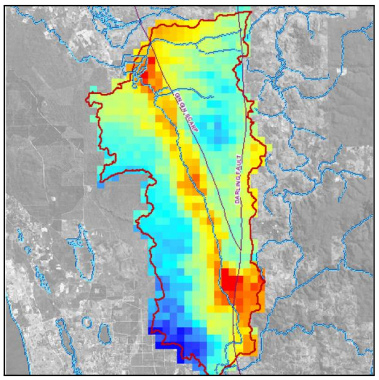
- Prepared a localised modelling domain SCERM29, spanning Belhus (upstream) to the Narrows (downstream) by extracting the domain from the original SCERM44 model.
- Prepared boundary conditions for 2018-2022 for both SCERM44 and SCERM29, and simulated 44 catchment inflows using Swan Canning Catchment Model eWater SOURCE, 2D meteorological forcing, and 2D water level and quality at the Narrows.
- Processed all available catchment, estuarine and oxygenation plants' water quality monitoring datasets for model inputs and validation.
- During validation processes, it was shown that model simulated temperature estimates experienced significant overheating in comparison to actual data in autumn. Further investigation suggested model flow constriction from Belhus to West Swan, which could not be overcome through model function modification. This indicated that bathymetry within the model was not correct and further data would need to be obtained.

**Management implications**

- The model will provide key understandings on the hydrodynamics (water level, temperature and salinity) and oxygen dynamics of the estuary based on a 5-year (2018-2023) validated period. This will assist the oxygenation plant managers to optimize the operation under present day condition and adapt to projections under future climate.

**Future directions**

- Undertake Swan River hydrographic survey from Bayswater Boat Ramp to Yagan Bridge (Belhus).
- Create new model meshgrids for SCERM44 and SCERM29 based on the new bathymetry survey results.
- Re-run SCERM44 and SCERM29 validations using new meshgrids for simulation period 2018-2023.
- Conduct flow measurements in continuous transects across the estuary.



## Ellen Brook catchment nutrient export: sources and pathways

SP 2022-033

S Adiyanti, K Trayler, A Basnett

**Context**

Ellen Brook is a tributary to the Swan Canning Estuary and is identified as the major contributor of nutrient loads to the system. Water quality in Ellen Brook catchment and its sub-catchments is influenced by a mixture of land uses and activities affecting both surface and groundwater inputs. Previous attempts have been made to model nutrient exports from the catchment but there remain uncertainties in the groundwater and land use type contributions to the overall nutrient export to the estuary. Refinement of nutrient modeling with inclusion of groundwater-surface water interactions is essential to reduce these uncertainties. To better inform land management policy and support decision making for nutrient interventions, a distributed, 2D, processed-based hydrological and nutrient model for Ellen Brook is being developed. The model will quantify nutrient export from specific land use types, differentiate active and legacy sources and illustrate spatial and temporal variability. Climate influence will also be considered.

### Aims

- Generate a hydrological and nutrient export model for the Ellen Brook catchment that will estimate the surface flux (discharge), baseflow, and regional groundwater contribution to nutrient export.
- Identify active and legacy sources contributing to stream nutrient load.
- Estimate the relationship between nutrient export and change in land use and land cover.
- Estimate the land use-specific nutrient export rate.
- Predict climate change impact and catchment management scenarios for Ellen Brook nutrient export.

### Progress

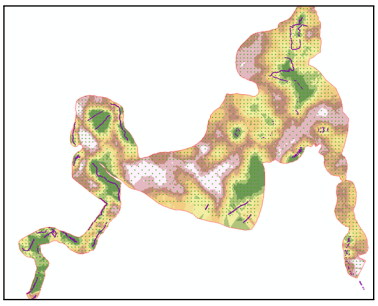
- Ellen Brook mesoscale hydrological model (mHM) structure has been developed with 100m resolution of gridded morphological data including: digital elevation, slope, aspect, flow direction and accumulation, soil characteristics, geological types, land use and land cover. In addition, at 1 km resolution, data includes daily meteorological parameters of evaporation, precipitation and air temperature.
- Simulated distributed flow at 1km resolution has been calibrated using recorded daily flow at two gauging stations.
- Within the catchment, surface water quality (at 34 monitoring stations) and groundwater levels and quality at multiple locations were processed and stored in a Matlab structure datafile for subsequent use in the model.

### Management implications

- Understanding the seasonal variations of nutrient concentration at each monitoring station and their relationship with flow will give an indication of whether nutrients are active or legacy types, which is critical information to assess how long it will take for water quality improvement measures in the catchment to come into effect and contribute to water quality targets.
- Development of the nutrient export model provides an opportunity to evaluate how land use change affects water quality, as well as how intervention options may assist in achieving water quality targets.

### Future directions

- In-depth investigation of soils, percolation, interflow, geology parameters utilised in Ellen Brook mHM and application of field data and previous investigation to support parameter derivation.
- Groundwater levels and quality data interrogation to gain an understanding of any key water quality parameters useful as a tracer to investigate groundwater contribution to stream flow.
- Preparation of monthly data of gridded soil moisture 1 km resolution, to enable soil moisture calibration inthe model.



## Mapping habitat in the Swan-Canning Estuary.

SP 2022-030

L Arrowsmith, J Baker, J Cosgrove, S Adiyanti, P Howie, K Trayler

### Context

Ocean sprawl is an increasing disturbance that is occurring along the Lower Swan-Canning Estuary (LSCE), replacing complex marine habitats with simplistic artificial structures, that can result in the decline of species richness and abundance. Using remote image collection methods (ROVs, drop-cameras, and tow-cameras) in conjunction with habitat classification systems, benthic surveys can be conducted across areas of importance to assist is assessing species abundance and extent of species reduction over time. As the LSCE is an important ecosystem for a range of species and habitats, as well as recreational users, collecting data to establish distribution maps of key habitats is essential to understand the influences of this system.

### Aims

- Produce broadscale habitat maps of the benthic habitat in the LSCE to inform assessments of benthic habitat diversity.
- Develop and consolidate maps of key species and communities and identify areas of ecological significance in the LSCE.

### Progress

- Images from the 2019 benthic surveys have been collected, cleaned and analysed using TransectMeasure.
- Benthic habitat images were collected during the February and March habitat mapping surveys. Images have been uploaded to Reef Cloud and analysis has begun to classify habitats.
- Production of maps using the TransectMeaure images began. This process has included exploration of modelling approaches to interpolate between data points.

### Management implications

- Benthic habitat maps identifying areas of ecological importance and benthic habitat coverage throughout the LSCE will inform development decision making.
- The methodologies and analyses used to develop these maps, provides a framework for future mapping, that will inform river managers about trends in benthic habitat.

### Future directions

- Continue to classify benthic habitat images and develop maps to illustrate high density areas of different species.
- Consolidate data across a range of taxa and habitats to develop benthic habitat maps.
- Integrating with Seagrass monitoring data to value-add and utilise data across the broader benthic habitat context.

## Habitat enhancement approaches within the Swan-Canning Estuary.

SP 2022-029

L Arrowsmith, J Baker, K Trayler

### Context

The Swan-Canning Estuary (SCE) is a microtidal system that has become subject to increasing urbanisation and development along its shorelines. As a result, river walls and rock revetments have previously been used to modify the shoreline and provide protection against erosion, often resulting in reduced natural habitats and species abundance. Eco-engineered habitats are an alternative method to aid in protecting shorelines and reducing erosion, whilst promoting biodiversity and alleviating declines in habitats. As existing modifications in the SCE reach the end of their intended lifespans and new structures are built to reduce erosion, there is potential to integrate eco-engineered technological and nature-based solutions in the SCE.

### Aims

- Evaluate and incorporate the use of Living Seawalls (LSW) habitat panels along three sections of the river wall within the lower SCE to assess their effectiveness in enhancing habitats.
- Provide baseline information on the effectiveness of two commonly used erosion control techniques for enhancing habitat.
- Determine the effectiveness of LSW panels for enhancing habitat percentage cover and richness along river walls compared to unmodified walls.
- Investigate the influence each habitat panel design has on colonisation rates and species diversity on all panels.

### Progress

- Living Seawalls habitat panels have been installed at three locations in East Fremantle.
- Three sampling trips have been undertaken to evaluate micro and macro scale species abundance on the panels.
- Work has been undertaken with the Town of East Fremantle (ToEF) to better secure the panels to the seawalls.

### Management implications

- The project is providing guidance to local governments on how to improve conservation of estuarine biodiversity by incorporating eco-engineering solutions into modified shorelines.
- Information on how panel application, type and positioning along a seawall influences species richness, abundance, cover and growth will inform planning decisions on the value of these approaches to improve habitat under Western Australian conditions.
- The methodologies, such as panel installation and suitability, as well as biodiversity assessment protocols will be used to inform other projects aimed at improving habitats along SCE shorelines.

### Future directions

- Measure species richness and percentage cover at the three sites.
- Continue 6 monthly sampling to assess the changes in the abundance and diversity of species and habitat.
- Investigate an alternative method to attach the panels to the seawall at low tides.

## Apply acoustic technologies to investigate fish communities and movement

SP 2020-029

S Hoeksema, J Baker, J Watsham, P Novak, K Trayler

### Context

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

Acoustic technology can be utilised to provide valuable information on fish movements relative to water quality parameters, such as salinity and dissolved oxygen, and to major interventions within the river system, such as the Swan Canning Oxygenation Program and the Kent Street Weir fishway. Acoustic technology can also be employed to understand how fish utilise habitats of differing complexity, particularly those that are not suited to traditional sampling methods. An acoustic array in the Swan Canning was established in 2016.

### Aims

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

### Progress

- Data on the movement of 120 tagged black bream were analysed relative to historic physico-chemical estimates from the Swan Canning Estuarine Response model.
- Acoustic receivers were re-distributed for tracking juvenile bull sharks (*Carcharhinus leucas*).
- Acoustic transmitters were attached to three juvenile bull sharks that were caught by gillnetting and targeted rod and line fishing.
- Longlines were trialed over summer in an attempt to improve catch rates but proved unsuccessful.
- Targeted gillnetting is now being incorporated into bull shark sampling.

### Management implications

- The application of acoustic receiver technology combined with water quality estimates derived from model outputs will help improve understandings of how fish populations respond to changes in environmental conditions and help to inform operation of the Swan oxygenation plants and Kent St Weir/fishway.
- Tagging bull sharks within the Swan Canning Riverpark will elucidate their movements in the Swan Canning Estuary to improve our understanding of residency time, distribution and habitat use to improve understanding of ecosystem condition and inform shark hazard risk mitigation strategies in the estuary and nearshore coastal environment.

### Future directions

- Continue analyses of bream movement relative to water quality.
- Expand the existing acoustic receiver array with additional receivers through the lower Swan Canning basin and undertake further bull shark tagging during the pupping season.
- Expand the investigation of bull sharks to include tagging of adult sharks in the lower in the Swan Canning Estuary and marine waters.

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

SP 2020-028

S Thompson, K Trayler

### Context

The Swan Canning system is a salt wedge estuary with many freshwater tributaries that have high biodiversity values. Five tributaries have been impounded for water supply purposes. With a growing urban population, demands for fresh water are increasing and finding the balance between the public water supply system and ecological requirements for water is increasingly challenging in a drying climate. It is important to understand the water requirements of freshwater dependent systems in terms of volume, timing and duration of flow to adequately protect them. When ecological water requirements are determined and water provision is set, it is appropriate to monitor to ensure values are maintained and expected outcomes are being achieved. The latter includes consideration of how in-stream barriers and other threatening processes can be managed to maximise value of the flow provisions.

### Aims

- Identify freshwater dependent biomes of ecological significance within the Swan Canning system, threatening processes, water requirements and potential for supplemental flows.
- Determine if there are detrimental impacts to ecosystems downstream of public water supply dams or water abstraction points.
- Determine connectivity of critical habitat and identify potential impediments to freshwater flows and movement of riverine biota. Assess in-river structures obstructing connectivity, potential ecological impacts and recommend options for management.
- Investigate novel approaches for assessment of freshwater biomes within the Swan Canning system.

### Progress

- Water provisions were monitored to ensure the prescribed water allocation to the lower Helena River was applied appropriately for maximum ecological benefit.
- Data for 207 potential barriers in the Canning River was consolidated into a GIS shapefile. Of these, 27 structures were characterised as significant barriers to ecological connectivity. Criteria to categorise the barriers for management actions were drafted and are undergoing validation and application to the barrier data.

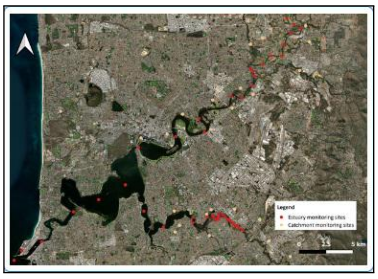
- Reference lists of aquatic fauna that might occur in the Canning River and tributaries were compiled, including fish, frogs, birds, mammals, reptiles and significant macroinvertebrates. These preliminary lists will support future biodiversity surveys and inform genetic reference libraries for future molecular survey work.
- Collaborative networks were developed with a wide range of groups in the Canning River and Helena River catchments to improve synergies and opportunities for future research and management activities.

**Management implications**

- Identification of in-river structures in the Canning River that are likely to significantly disrupt instream habitat connectivity enables prioritisation of removal or modification of structures to improve connectivity, ecological function and native fish movement.
- Data on flow related values, water quality and biota is informing the Canning Waterways Restoration Plan, evaluation of the Canning water provisions and catchment management plan for the Helena River.

**Future directions**

- Finalise transfer of the barriers database into a GIS based framework that supports decision making and provides a tool for management.
- Based on environmental water studies, develop recommendations for water provisions for the lower Helena River.



## Swan Canning Water Quality Monitoring

SP 2020-027

J Cosgrove, J Watsham, P Howie, J Chapman, A Gillies, P Novak, J Gregory, S Thompson, S Muller, A Saeed, K Trayler, S Hoeksema

**Context**

Water quality in the Swan Canning Estuary and its catchment has been routinely monitored over the past 25 years, producing one of the largest continuous data sets for any estuarine system in Australia. Data produced through the monitoring program provides essential information to assess system response to management actions, changes in estuary condition over time and is used to report against estuary water quality targets, catchment nutrient reduction targets and phytoplankton trigger levels. Data has also been used to progress the development of estuarine and catchment models that contribute to decision support.

**Aims**

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

**Progress**

- Weekly water quality profiles were taken at up to 42 sites and weekly phytoplankton and fortnightly nutrient samples were collected at 21 sites throughout the estuary.
- Water quality reports and phytoplankton information were updated weekly on the Eyes on the Swan Canning Riverpark web page.
- An online data reporting dashboard featuring site maps and multiple data layer continues to be explored, with a Beta version expected in the second quarter of 2023-24.

- Review of monitoring has resulted in some efficiencies being implemented, with sites monitoring Canning River oxygenation being reduced from 12 to 5 and some chemical analyses dropped.
- Historical monitoring data was used to develop local baseline water quality triggers for major works around the river.

**Management implications**

- Routine water quality monitoring has value in protecting the Swan Canning Riverpark, by allowing development of locally relevant water quality triggers for inclusion into environmental management plans.
- The online dashboard will replace public facing weekly updates and annual data reports and present monitoring data to the public in a more timely and interactive manner.
- Information on potential public health risks, such as algal blooms, black-water events and fish-kills have been passed on to Department of Health, Department of Primary Industries and Regional Development and DBCA incident management teams as required.

**Future directions**

- Complete phase 1 of the web-based dashboard and interactive portal to present water quality data.
- Implement changes to phytoplankton monitoring as recommended by monitoring review.
- Finalise the production of technical report on Swan Canning condition (2015-2020).

## Investigations of contaminants in the Swan Canning

SP 2020-026

P Novak, S Hoeksema, K Trayler

**Context**

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

**Aims**

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

**Progress**

- Three reports on contaminants in the Swan Canning Estuary and catchment were completed and published. These were on the distribution, extent and sources of per- and polyfluoroalkyl substances (PFAS) contamination in surface waters, blue swimmer crabs and black bream; the concentration and composition of contaminants in western school prawn; and change in sediment contamination.
- A journal article on PFAS in the Swan Canning Estuary has been published in *Marine Pollution Bulletin* and identifies multiple sources with levels of estuarine contamination influenced by the historical usage timeframe, groundwater interaction and surface water discharge.

- Sampling to determine the effectiveness of the Ellen Brook constructed wetland in removing and storing PFAS from surface water, has been completed. A data report is in progress.

**Management implications**

- Information on the distribution and concentration of contaminants in the estuary is used to identify the potential environmental risk to the estuary.
- Analysis of PFAS in surface water in the estuary indicates low risk. Three surface water catchments where PFAS concentrations were elevated have been identified, and the information has informed initiation of management activities to mitigate PFAS runoff.
- Evaluation of PFAS levels in black bream, and blue swimmer crabs, and contamination in western school prawns, provided evidence for decisions on health risk to recreational fishers from consumption of these species.
- Sediment contamination in 2015 was largely consistent with that in 2007 and provides a useful baseline for determining contaminant change over time and in response to management action. Information on sediment contaminant levels informs development planning approvals and highlights zones where risks associated with contaminant disturbance are greatest.

**Future directions**

- Complete report on the effectiveness of the Ellen Brook constructed wetland to remove PFAS from surface water.
- Preparation of a manuscript on PFAS in biota.

## Incident investigations, response and advice

CF 2018-095

K Trayler, J Cosgrove, P Novak, S Thompson

**Context**

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

**Aims**

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

**Progress**

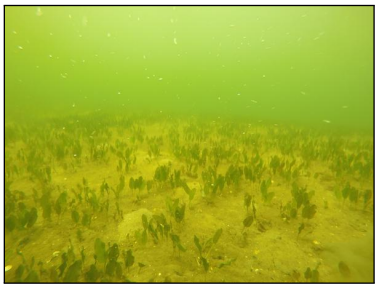
- Algal bloom response plans were updated prior to commencement of the bloom season.
- Four algal blooms were monitored, with three requiring formation of an incident management team and provision of alerts to stakeholders and/or the public.
- Additional monitoring and inter-agency incident response team meetings occurred in response to *Alexandrium* exceeding trigger levels from 13 February to 13 March, a toxic cyanobacteria bloom in the Canning River and to *Karlodinium* blooms.
- In response to reports of two serious cases of vibriosis anecdotally linked to the Swan Canning Estuary, additional monitoring was undertaken to support internal occupational health and safety advice.
- Response was provided to a black-water event caused by heavy rains at the end of March 2023.

### Management implications

- Monitoring results and scientific advice effectively supported response management actions.

### Future directions

- Respond to river incidents and involve key stakeholders and other management agencies where necessary.
- Provide advice, as required, to Rivers and Estuary Branch incident teams and statutory assessments unit.



## Seagrass monitoring and evaluation

SP 2018-039

J Cosgrove, C Phelps, P Howie, J Watsham, J Chapman, A Gillies, S Muller, K Trayler

### Context

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

### Aims

- Describe the variability of several seagrass characteristics including seagrass cover, species composition and seagrass reproduction in response to possible changes in key environmental and climatic conditions.
- Understand the sensitivity of seagrass metrics in response to anthropogenic stressors such as water quality, sediment stress, drift macroalgae load and invasive species.
- Integrate benthic assessment data with habitat mapping data to produce a benthic habitat map of the estuary, which includes seagrass population distribution.

### Progress

- Annual seagrass sampling was conducted within the Swan Canning Estuary. Seagrass presence was lower in 2022-23 compared to the previous season. This may be attributed to a lower global solar exposure this season, however seagrass performance was still rated as ‘good’.
- The high seagrass presence in the 2021-22 season increased reproductive success this season, with the number of flowers/fruits/seeds all increasing compared to last season.
- Analyses determined that the invasive snail, *Batillaria australis,* reduced considerably (>60%) between 2017 and 2019, potentially due to the freshwater influx through the 2017 high rainfall event.
- Benthic habitat mapping progressed through shoreline ground truthing and drop-cam image collection. Drop-cam images have been processed and will be used to train habitat classification algorithms applied to new WorldView-2 satellite images.

### Management implications

- Seagrass metrics and key drivers of environmental conditions provide indicators of river health and maintenance of water way condition. They are being incorporated into the yearly reports (2021-22 and 2022-23) on the waterway and have been used to support reporting on the River Protection Strategy.
- Updated maps of seagrass distribution will allow more accurate considerations of benthic impacts by developments in and around the Swan Canning Riverpark.

### Future directions

- Finalise seagrass annual reports.
- Initiate high resolution seagrass productivity transects, and analyse nutrient content in seagrass biomass and sediment to gauge changes in environmental biochemistry and subsequent seagrass health.
- Explore microbiological approaches to sediment sampling for indicators of potential chemical stress.

## Algal blooms: investigations and control

SP 2018-035

J Cosgrove, K Trayler, S Thompson, S Hoeksema

### Context

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

### Aims

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

### Progress

- Where harmful algal species were detected in the waterway, investigation of blooms across spatial and temporal scales was undertaken to build understandings of conditions that influence these events.
- Liason with Rivers and Estuaries Branch and Department of Health yielded opportunities to manipulate the Kent Street Weir operations in an attempt to disrupt local blooms.

### Management implications

- Continued routine water quality monitoring and targeted response sampling to detect harmful algal blooms enables rapid local toxin testing and improved incident management.
- Careful management of Kent Street weir may reduce bloom impacts in limited circumstances, although multiple management priorities govern weir manipulation and careful ranking of these priorities is required.

### Future directions

- Work with internal partners to develop a framework for manipulation of Kent Street Weir, that can contribute to bloom prevention while enabling other management priorities to be achieved.
- Investigate long-term algal bloom dataset and historical management actions in the Kent St weir pool to understand key drivers influencing bloom intensity and frequency.
- Undertake toxicity trials to ascertain environmental safety of Kaolite clay+poly-alum chloride as a tool for algal bloom control.

# Investigating fish communities as an indicator of estuarine condition

SP 2018-033

K Trayler, J Baker, J Watsham

## Context

Fish communities exhibit predictable responses to ecosystem degradation and stress, and thus may be used as sensitive indicators of the ecological condition of these systems. Biotic indices, based on fish and other biological communities, are now used worldwide to quantify the ecological health of rivers, lakes, estuaries and many other environments. This project applies a Fish Community Index (FCI) developed by Murdoch University in collaboration with government agencies (2007-12) as a measure of the condition of the Swan Canning River system. This has been part of regular monitoring and reporting on the waterway since 2012 and a report on fish communities in the Swan Canning Riverpark is released to the public annually.

## Aims

- Undertake evaluation of the fish communities in the Swan Canning Riverpark for the purposes of applying the Fish Community Index of estuarine condition and reporting.

## Progress

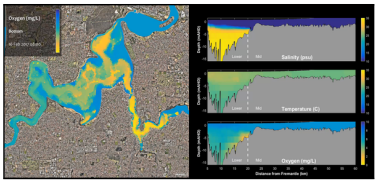
- A report documenting the 2022 fish community index (FCI) results was completed.
- In the 2022 season, the combined scores for offshore and nearshore sites were the best recorded over the last decade of monitoring. These were attributed to strong flows in the winter of 2021, which were the best in 25 years.
- Scores in offshore waters of the Canning Estuary were poorer in comparison to other zones and this result continues an historic trend.
- Further investigation of this trend identified that the low FCI scores were influenced by low number of species and diversity and a high proportion of detritivores in the offshore waters of the Canning. Low dissolved oxygen did not appear to be a factor driving these results.
- A report on the 2023 season is in preparation.

## Management implications

- The good overall FCI scores in 2022, and particularly in the Swan, were a function of strong winter flows and good water quality, including low densities of harmful algae and oxic conditions through summer and autumn. This provides for better understanding of environmental factors influencing fish communities in the system.
- The causes of comparatively poorer scores in offshore waters of the Canning and the potential need for management response are yet to be determined.

## Future directions

- Complete report documenting the results of the 2023 sampling.
- Continue monitoring in summer and autumn.



## Model frameworks for estuarine reporting

SP 2018-027

K Trayler, J Watsham

### Context

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

### Aims

- Evaluate optimal water quality data requirements for predictive modelling of estuarine conditions.
- Develop a display showing near real-time data.
- Validate model forecasts and hindcasts.
- Enhance understanding of estuarine dynamics.

### Progress

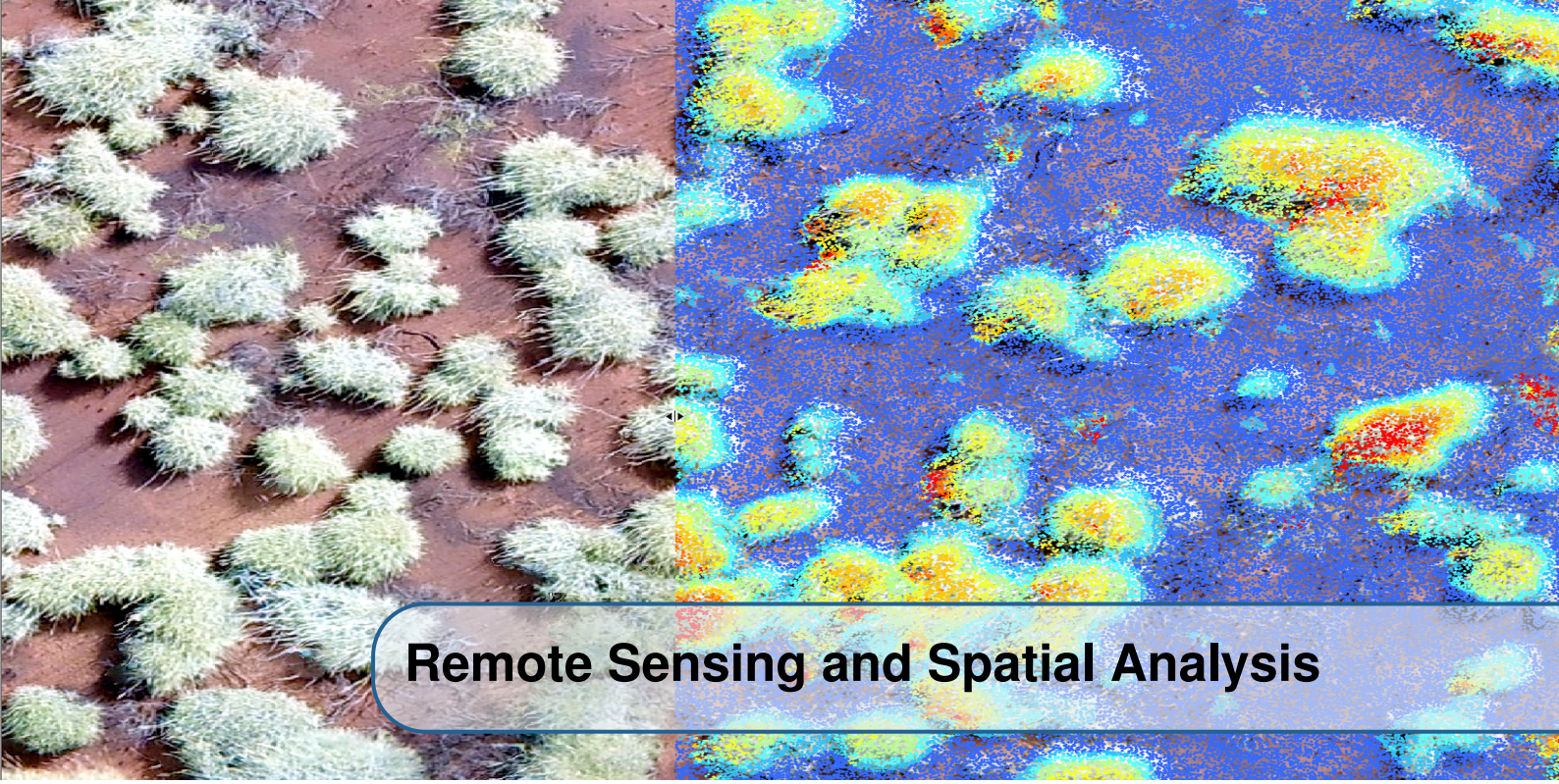
- Hindcast water quality datasets from 2012-2020 that were generated by the Swan Canning Estuarine Response Model (SCERM44) were queried and used to support investigation of factors that may underly poor Fish Communities Index scores for offshore areas of the Canning Estuary.
- Preliminary assessment of the water quality and biological datasets suggest that low oxygen was not a key driver of poor Fish Community Index scores.

### Management implications

- The Swan Canning Estuarine Response Model (SCERM44) is a useful tool for both predictive and hindcast determination of water quality conditions. Ongoing updates and validation is essential to ensure this management tool remains relevant.

### Future directions

- Further progress the analyses of hindcast model outputs relative to biological datasets.
- Continuous improvement in model frameworks.



# Remote Sensing and Spatial Analysis

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

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

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

## Novel methods combining ground-based monitoring and remotely sensed observations to inform management and measurement of ecosystem condition in the rangelands

SP 2021-011

J Ruscalleda Alvarez, K Zdunic

### Context

The mulga rangelands of the Midwest have experienced long-term degradation from the cumulative impact of 150 years of pastoral activity. Changing precipitation regimes and increasing temperatures threaten to further modify the trajectory of ecological condition in these ecosystems, with the impact of vegetation mortality and invasive species both likely to become more pronounced in future decades. However, while the extent of degradation is widely acknowledged, it is not known whether these ecosystems have the ecological capacity to naturally recover when agricultural grazing pressures are removed or how resilient they might be to future climatic extremes.

### Aims

- Deliver new insights into the functioning of rangeland ecosystems in WA, and tools to undertake future monitoring and evaluation of these ecosystems.

- Develop a method to relate remote-sensing based measurement of ecosystem condition to on-ground monitoring datasets.
- Integrate new remote sensing technologies into assessments of rangeland condition and change detection.
- Determine the recovery potential of degraded rangeland ecosystems in Western Australia.

**Progress**

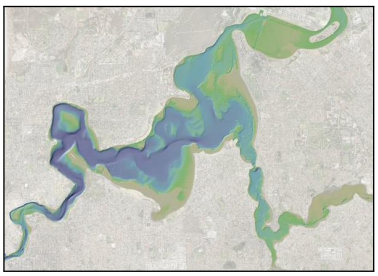
- Developed a model of vegetation cover based on high resolution imagery and training Landsat satellite imagery with terrain variables.
- Initiated investigation of vegetation structural attributes through radar and optical satellite imagery (Sentinel 1 and 2).
- Obtained de-identified West Australian Rangeland Monitoring Sites (WARMS) data from DPIRD to differentiate climate and grazing impacts on shrub community dynamics.
- Processed remote piloted aircraft imagery and lidar data captured during field trips in 2021 and 2022 to derive site based vegetation cover and structure attributes.
- Further processed airborne LiDAR to improve derived products of canopy height and cover.

**Management implications**

- Identifying the recovery potential of particular areas of the landscape allows land managers to design targeted interventions in areas either most at risk of further degradation, or in places with the greatest potential to recover.
- Developing new remote-sensing based monitoring methods will allow more spatially comprehensive assessments of changes in vegetation condition than are currently practicable.

**Future directions**

- Publish papers from analysis examining growth rates, mortality and recruitment of dominant woody shrubs, and changes in shrub community compositions in relation to changes in ecological condition of sites.
- Develop a method to map rangeland vegetation cover and structure from a fusion of imagery types.



## Spatial data management

CF 2018-075

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

**Context**

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

**Aims**

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

### Progress

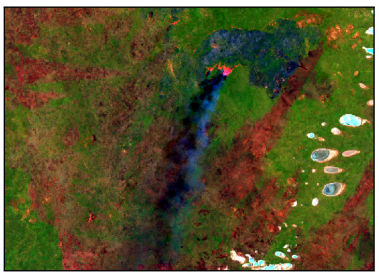
- Applied processes to make spatial data discoverable and accessible as the department moves data storage to a cloud environment.
- LiDAR data sets purchased by other state agencies were obtained and included for corporate use.
- Bathymetry data loggers installed on three Kimberley vessels have started to contribute data to a crowd sourcing bathymetry program run by Geoscience Australia's AusSeabed program.
- A review of data management protocols was undertaken and new protocols implemented.
- Undertook development and training in access and application of scripts to enable access and processing of satellite imagery maintained on the national computing infrastructure.

### Management implications

- Terrestrial and marine spatial data of corporate value can be accessed internally using cloud-based platforms, and data that is of value to external stakeholders can be identified, documented and made available on portals such as DataWA.
- Making available updated state-owned LiDAR and other data reduces duplication and increases the capacity of spatial modelling of soils, vegetation and habitats for management.
- Bathymetry data from regional patrols can now contribute to AusSeabed that will assist department staff in navigation, management and monitoring operations in Kimberley Marine Parks waters.
- Continued development and migration of user-friendly spatial data sets will support the department's need to improve the discoverability and accessibility of science data for all staff.
- Spatial information on the juvenile period of flora species provides information on fire intervals and supports decision making during prescribed burn planning.

### Future directions

- Identify terrestrial and marine spatial data sets to be migrated to the corporate data menu.
- Continue to update satellite imagery, LiDAR and digital elevation model catalogues.
- Continue to develop scripts and functions to utilise satellite imagery on national computing infrastructure.
- Collaborate with Geoscience Australia's AusSeabed program and Intertidal product suite to improve coastal bathymetry and the definition of tide marks in the Kimberley.



## Remote sensing and spatial analysis for fire management

CF 2018-074

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

### Context

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

### Aims

- Improve processes of fire scar identification to enable historical fire regimes to be understood for safety and ecological applications.

- Improve burn security through development of methodology to detect and communicate hotspot locations.
- Develop techniques to provide inputs for fire behaviour models to enable desktop assessments.
- Carry out operational processing of fire severity maps for prescribed burn and expand the historical archive.
- Provide remotely sensed spatial and temporal data to assist with bushfire investigations and reporting.

**Progress**

- Fire scar information for the Pilbara and Goldfields regions, Kanyirninpa Jukurrpa, Desert Support Services and Tarlka Matuwa Piarku was supplied to inform and report on prescribed burning activities in the Western Desert and Pilbara regions.
- Supported the operational use of airborne thermal cameras to detect hotspots for burn security.
- Supported the use of thermal sensors on remote piloted aircraft for monitoring fire behaviour during studies in prescribed burns.
- Continued investigation into remote piloted aircraft based LiDAR for fuel accumulation modelling and fire behaviour response.
- Supported regional and district fire managers in interpreting satellite derived burn severity products.
- Fire severity mapping process was implemented to an operational level, with the system progressed to provide monthly updates through the prescribed burn seasons.
- Historical burn severity mapping was completed to cover the majority of the Perth Hills district.
- Developed an R software package (FireHistory) for Fire Science and the public to enable fast querying and analysis of DBCA fire history data.
- Provided data to Fire Management Services Branch to inform fire recovery, fire chronology and emerging satellite technology and availability.
- Continued integration of a satellite derived spinifex fuel cover model with the Pilbara region.
- Testing of automated fire scar mapping in the Great Victoria Desert was undertaken in collaboration with Landgate and the Great Victoria Desert Biodiversity Trust.
- Mapping of fire scars across the Great Western Woodlands for the year 2021-22 and improvement of the mapping archive to 1972 was undertaken by Landsat image analysis.

**Management implications**

- The information provided for fire management is designed to significantly increase the accuracy of reporting and decrease the risks of fire management activities. Delivering fire scar mapping and information allows practitioners to make informed decisions that lead to more efficient fuel reduction activities and successful completion of burn prescriptions.
- Effectively processing the DBCA fire history data provides quantitative and current statistics on fire frequency, number of repeat fires and fire interval.
- Consistent production and attribution of seasonal fire scar mapping have resulted in the compilation of an annual fire scar mapping product with improved date, area and cause attribution. This product is suitable to analyse and provide spatial metrics that will aid in assessing the effectiveness of the fire management program over Millstream Chichester and Karijini National Parks.
- Delivery of aircraft-based thermal imagery hotspots to on-ground staff improves the security of burns.
- Development of a new cost-effective method for ground staff to assess burn security by detecting boundary hotspots from a remote piloted aircraft can be more efficient in more remote areas or when visibility is limited from an aircraft.
- Using remote piloted aircraft based LiDAR for fuel height and density measurement will lead to a more accurate model of fuel accumulation for better management of fuel levels in the forest and safer bushfire management.
- Satellite derived spinifex fuel cover maps enable regional fire activities to be more targeted, efficient and safe in their fuel reduction activities.
- Fire history information in the Great Western Woodlands will be used to identify locations vulnerable to fire regime change and guide burn planning to protect these vegetation communities.

**Future directions**

- Continue development and automation of fire scar detection methodology.
- Investigation and development of new data sources including emerging satellite sensors and aerial capture.
- Continue testing and operalisation of fire severity models in south west forests.

- Implementation and development of spatial analysis of fire patterns and fuel loads.
- Assist in in implementing safe use of remotely piloted aircraft with thermal sensors for studies in fire behaviour and for burn security.

## Spatial analysis and modelling

SP 2018-073

J Kinloch, K Zdunic, G Loewenthal, B Huntley, G Pitt

### Context

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

### Aims

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

### Progress

- A habitat suitability model for the yellow-spotted monitor (*Varanus panoptes)* was extended east to include the Yampi Peninsula. The new version also incorporated observations collected by Traditional Owner Ranger Groups into the modelling.
- Existing native vegetation extent mapping was used along with the LandMonitor vegetation extent time-series to map, with confidence ratings, the 2021 remnant vegetation extent across the Wheatbelt.
- Spatial variables were developed for the North West Shelf flatback turtle rookeries and at-sea distribution models and a research manuscript has commenced.
- Feature requests were added to software developed for data parsing oxygenation metrics for Rivers and Estuaries Branch.
- Improvements to interpolation methods applied in the rivRmon R software package developed for Rivers and Estuaries Science were undertaken.
- Regional conservation planning processes were supported with spatial analysis, including fauna and threat matrix compilation for the South Coast region.
- Undertook spatial analysis to support investigation of climate impacts on threatened flora populations across the Stirling Range National Park.
- Further developed landscape function analysis metrics based on 2022 captured remote piloted aircraft imagery and evaluated these against ground assessed landscape function analysis measures.

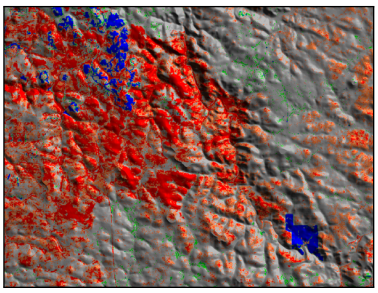
### Management implications

- Spatial information on where significant habitat of the yellow-spotted monitor is likely to occur will be used to optimise the location of cane toad taste aversion training.

- Species distribution models provide information on the likelihood of habitat for a species being present and thus are critical for determining species conservation and management priorities and actions.
- DBCA has a requirement for up-to-date remnant vegetation extent mapping as an input into species habitat mapping and assessment of the impact of fragmentation on species.
- Information on the conservation values and threats present in each conservation management unit, contributes to the identification of management priorities during DBCA's regional conservation planning process.
- R software solutions have provided robust and easy to use tools to significantly simplify data analysis for DBCA scientists and the public.
- The identification of refugia for threatened flora populations can be used to inform management to mitigate the impact of climate change.
- Monitoring of changes in vegetation cover and landscape function will assist in determining the effectiveness of feral herbivore control measures and other conservation actions on the Fortescue Marsh.

**Future directions**

- Further develop landscape scale spatial metrics that assess conservation values and threats that can be used for monitoring management interventions.
- Develop models for the yellow spotted monitor in other locations along the cane toad front.
- Further develop spatial resources and tools to support the South Coast strategic planning.
- Develop further functionality for the DBCA fire history analysis software to include additional metrics.
- Incorporate new survey areas into the Swan and Canning Bathymetry.



## Remote sensing monitoring

SP 2018-072

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

**Context**

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

**Aims**

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

**Progress**

- 30 year mangrove time-series products have been processed using analysis ready Landsat and Sentinel 2 satellite imagery for Lalang-garram Marine Park reporting.
- Millstream Chichester National Park riparian vegetation monitoring was continued. A refinement of the land system mapping to land unit was also undertaken over the park.

- Developed a method for detecting exposed intertidal seagrass extent from remotely piloted aircraft ground truthing in collaboration with Yawuru Traditional Owners using 2020 Sentinel 2 satellite imagery.
- Development of a field monitoring protocol supporting the Fortescue Marsh management strategy was undertaken with initial field sites established on the marsh.
- Wetland inundation and hydroperiod analysis for various wetlands throughout the state was undertaken utilising satellite imagery.
- South west wetland monitoring program data reanalysis is being progressed.
- Real-time kinematic remote piloted aircraft image and LiDAR processing workflow for Ramsar and other wetland fringing vegetation is under development with multiple tests conducted over Lake Mclarty.
- High resolution satellite imagery and field data were applied in a machine learning model to map seagrass habitat in Geographe Bay.
- Remote piloted aircraft capture testing using a variety of sensors was undertaken at Benger swamps in order to develop appropriate measures to manage bittern habitat.
- Continued development of cover and structure measure from close range and satellite remote sensing of the Badimia reserves to support carbon projects.
- Undertook survey and remote piloted aircraft data capture of known populations of critically endangered *Grevillea acropogon* in the Warren District.
- Completed reports summarising changes in rainfall, vegetation cover trends and fire history metrics across Yanchep, Neerabup, Shannon, D'Entrecasteaux, Tuart Forest National Parks and the Ord River and Parry's Lagoon Nature Reserves.
- Completed classification of remote piloted aircraft imagery data at drought sites in the Northern Jarrah Forest.

**Management implications**

- The large tidal range of Yawuru Roebuck Bay has previously made monitoring of culturally and ecologically important intertidal seagrass difficult. The development of an exposed intertidal seagrass extent product from satellite imagery is facilitating annual reporting on intertidal seagrass for the first time and providing insights into the maintenance of dugong habitat.
- Wetland inundation and hydroperiod analysis provides information to understand the status and conservation significance of wetlands especially those remotely located.
- Evaluation of wetland characteristics is informing locations of suitable habitat for threatened species.
- Real-time kinematic remote piloted aircraft image and LiDAR processing workflows will enable repeatable analysis and the development of a framework for vegetation monitoring.
- Development of consistent monitoring protocols supporting site and landscape scales of changes in vegetation cover will assist in determining the effectiveness of conservation actions on the Fortescue Marsh.
- Mangrove monitoring information provides quantitative locational changes of mangrove canopy informing management action and is applied in Conservation and Parks Commission reporting.
- Improved landscape mapping resolution aids management at scales relevant to parks and reserves.
- Vegetation monitoring across various environments including mangroves, riparian zones, rangelands and forests, provides quantitative information for assessing vegetation changes and informs management actions.
- Management plan evaluations for several National Parks and Nature Reserves is supported by satellite imagery analysis and spatial data analytics.
- Through measurements and classification of imagery captured using remote piloted aircraft, the size and density of trees in drought impacted areas in the jarrah forest is informing forest management to mitigate drought impacts.

**Future directions**

- Undertake research and develop inputs to Forest Management Plan reporting including forest health monitoring and program development.
- Continue research into forest condition with a focus on resilience.
- Develop habitat mapping for endangered species in Dryandra woodland.
- Continue to explore and develop cloud processing options with Geoscience Australia.
- Develop and refine the use of remotely piloted aircraft imagery and LiDAR for vegetation monitoring and mapping. Including the development of capture specification and analysis pathways to determine

vegetation structure and cover attributes.
- Apply mangrove monitoring methodology through remote piloted aircraft ground truthing and satellite imagery upscaling in Roebuck Bay/Yawuru and 80 Mile Beach Marine Parks and test the accuracy of the products developed for Lalang-garram Marine Park.

## Dirk Hartog Island vegetation monitoring

SP 2018-009

R Van Dongen

### Context

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

### Aims

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

### Progress

- Vegetation cover change was analysed with 42 percent of the island experiencing a significant increase since destocking.
- Captured imagery over many of the monitoring sites with a new multispectral remotely piloted aircraft (RPA). The new RPA has improved positional accuracy allowing more detailed assessments of change.
- Data collect by the monitoring program from 2015 to 2021 is now being processed to align with the 2022 imagery. Detailed measurements of changes to vegetation extent are also being made. These measurements will form part of a comprehensive statistical analysis.

### Management implications

- Results from the program demonstrate the ecological benefits of the eradication of introduced species and provide evidence that, with the improvement in vegetation condition, the mammal reintroduction program has a high likelihood of success.
- The data collected and further study of the fauna exclusion plots will aid in measuring the impacts of the reintroduced fauna.

### Future directions

- Update vegetation monitoring and sand dune area movement using Landsat imagery and carry out field validation of vegetation change.
- Continue assessment of changes to buffel grass extent over the period 2015 to 2022 and further investigate buffel grass detectability.
- Carry out field identification of plants that have significantly changed in extent over the 2015 to 2022 period and provide growth and cover statistics.

# Species and Communities

**Program Leader: Ruth Harvey** Species and Communities Program supports the delivery of the *Conserving Habitats, Species and Ecological Communities Service* through the provision of biodiversity knowledge with consistent and reliable products and information and advice regarding: legislation and policy development and interpretation; planning and setting priorities; implementing biodiversity conservation programs; maintenance of data and other information and community engagement. The program supports the department's operations in the areas of conservation of threatened fauna, flora and ecological communities conservation; fauna and flora management; wetlands and off-reserve conservation. It administers the departmental Animal Ethics Committee and provides support to the Threatened Species Scientific Committee and the Threatened Ecological Communities Scientific Committee.

## Biodiversity knowledge management

CF 2023-041

J Donaldson, J Chick, A Cooke, M Greenwell, R Harvey, B Meagher, C Sands, E Skey, Y Skinner, S Williamson, R Wright

### Context

The *Biodiversity Conservation Act 2016* (BC Act) provides the statutory basis for listing species that are at risk of extinction and ecological communities that are at risk of collapse as threatened. Processes for listing species and ecological communities as threatened depend on accurate and comprehensive biodiversity knowledge. Threatened species and ecological communities knowledge is also required by environment-related sectors including government, industry and research organisations to inform conservation and management planning and decision making.

### Aims

- Ensure the list of threatened species and communities ecological communities under the *Biodiversity and Conservation Act 2016*, remains up-to-date as threats change and scientific understanding improves.
- Ensure that listing processes are robust and involve scientific, operational, community, stakeholder and government consultation in a manner consistent with contemporary expectations, and administer the Threatened Species and Threatened Ecological Communities Scientific Committees and the Common Assessment Method Framework.

- Maintain relevant departmental policies for the administration of the legislative process for maintaining conservation lists, and administrative process for Priority listings.
- Maintain contemporary, integrated and accessible databases, data catalogues, and data management systems, with appropriate data standards.
- Collect and curate data for conservation listed species and ecological communities, and make available as appropriate.

**Progress**

- The first list of threatened species under the BC Act was gazetted.
- As at 30 June 2023, there were 436 (163 critically endangered, 143 endangered and 130 vulnerable) threatened flora species including ten additions, three delistings and 16 name changes.
- As at 30 June 2023, there were 248 (57 critically endangered, 59 endangered and 132 vulnerable) threatened fauna specie including one delisting and five name changes.
- The first list of threatened ecological communities under the BC Act was gazetted in May 2023.
- As at 30 June 2023, there were 65 (45 critically endangered, 9 endangered and 11 vulnerable) threatened ecological communities. There were 35 category and criteria changes from the previous list as a result of assessment using the standardised International Union for the Conservation of Nature Red list for Ecosystems assessment criteria.
- Priority lists were maintained. As at June 30 2023 there are 3454 species of Priority flora, 220 species of Priority fauna, and 390 Priority Ecological Communities.
- Work on development of the Boranga database continued with the Office of Information Management and engagement with the Biodiversity Information Office to ensure integration and functionality with other Corporate systems.
- Data for conservation listed species continued to be entered and curated in existing data bases. 25,213 occurrence records for threatened and priority species (21,593 fauna and 3685 flora) and 671 ecological communities were added to or modified in DBCA corporate databases.
- The data provision service managed 1964 data search requests for threatened and priority flora (783), fauna (569) and ecological communities (612).

**Management implications**

- Maintaining threatened species and ecological communities lists with accurate and up-to-date scientific information provides an improved basis for conservation and government decision making.
- The priority species and ecological communities list assists in identifying priorities for conservation planning and reserve management actions, and affords some protections through the *Environmental Protection Act 1986.*
- Availability of biodiversity knowledge to government, consultants and other external stakeholders improves the basis for environmental planning and decision making.

**Future directions**

- Continue to identify and add new additional data and improve sharing through the Dandjoo platform, to increase visibility of conservation actions, threats and management requirements of threatened species and communities.
- Implement the Boranga database.

# Wetlands conservation

CF 2023-020

H Bucktin, R Harvey, A Pinder, K Schell

## Context

Wetlands provide essential habitats for many native fauna and flora species and migratory birds, as well as providing essential ecological services, such as reducing the severity of floods, providing refuges for wildlife during drought, carbon sequestration and filtration of sediments, nutrients and pathogens. The Ramsar Convention on Wetlands is an intergovernmental treaty that provides the framework for the conservation and wise use of representative, rare and unique wetlands, wetlands important for biodiversity conservation and their resources. Being a signatory to the Ramsar Convention, Australia has undertaken to ensure our internationally important wetlands are conserved. There are 12 Ramsar wetland sites in Western Australia.

## Aims

- Provide input to policy development for wetlands of high conservation value in accordance with the Ramsar principles and promote the wise use of wetlands.
- Provide scientific and technical guidance to site managers for conservation of wetland values.
- Contribute expertise to adaptive management and consider climate change adaptation measures.
- Collaborate with the Commonwealth government and with key stakeholders to deliver responsibilities under the Ramsar Convention.

## Progress

- Site inspections were undertaken with on-ground managers for all 12 WA Ramsar wetlands. Information from site inspections and regular communication with managers is informing the development of a framework to improve management, monitoring and reporting of ecological condition of Ramsar sites in WA.
- Six-monthly reports to the Commonwealth were completed, and discussions with other States focused on developing a strategic approach to managing and reporting on Ramsar wetlands.
- Ramsar Information Sheets were updated for Lake Gore and Becher Point Ramsar sites and entered into the online Ramsar Sites Information Service.
- Participated in a national Ramsar workshop to improve ecological condition reporting nationally as a case study to adopt globally.
- Potential projects for Ramsar wetlands were discussed with Natural Resource Management groups and on-ground managers.
- Participated in a climate change case study workshop held by the National Environmental Science Program Climate Systems hub.

## Management implications

- Development of a strategic approach to managing and reporting on Ramsar wetlands will clarify roles and responsibilities for monitoring, managing and reporting on Ramsar wetlands in WA.
- Updating Ramsar Information Sheets, and condition reporting, assists in meeting national obligations under the Ramsar Convention.
- Working with on-ground managers and Natural Resource Management groups builds capacity to deliver collaborative management and restoration projects for Ramsar wetlands.

## Future directions

- Finalise and implement the strategic framework for monitoring, managing and reporting on Ramsar wetlands in WA.

- Continue to work with Natural Resource Management groups, the Commonwealth and stakeholders and provide leadership in collaborative adaptive management and climate change mitigation for high conservation value wetlands and Ramsar sites.
- Continue to work with scientists and on-ground managers to collate information on the status of Ramsar wetlands and report to the Commonwealth.

## Flora conservation and recovery

CF 2023-019

T Llorens, R Harvey, A Hutchinson, K Schell

### Context

Flora is listed as threatened under the *Biodiversity Conservation Act 2016* (BC Act) when it is at risk of extinction in the wild and the BC Act provides a number of statutory mechanisms to conserve and recover threatened and other native plant taxa. Provision of expert scientific advice to guide the application of statutory conservation and management planning, regulation and on-ground implementation, improves conservation outcomes for the State's flora.

### Aims

- Provide up to date scientific advice for management, protection and recovery of threatened and priority flora.
- Ensure that recovery programs for threatened species, including translocations, are evidence-based and effective
- Inform policy and strategic direction relating to flora using up-to-date science.
- Leverage stakeholder involvement in recovery teams.
- Provide advice to land managers on appropriate fire management strategies.
- Provide scientific advice to prioritise and develop IUCN assessments for priority and threatened species.
- Use best-available scientific information to ensure licensing and harvesting decisions are evidence based.

### Progress

- Provided expert technical advice towards combined assessments and conservation advices led by the Commonwealth government for nine flora species.
- Conservation status assessments resulted in 68 additions to the priority flora list, change in category of 13 taxa, and delisting of 26 taxa after survey and taxonomic review clarified their conservation status.
- Provided advice and support to internal and external stakeholders on recovery actions and land management activities to support conservation of threatened flora.
- Approved three translocation proposals, two for internal proponents and one for an internal-external partnership. Assessed four external translocation proposals and provided advice to potential proponents.
- Provided scientific advice to inform recovery strategies at threatened flora Recovery Team meetings for Albany and Esperance Districts and for two meetings of the Goldfields Region.
- Provided technical and scientific advice was provided on environmental impact assessments including Section 40 authorisations to take threatened flora under the BC Act, on applications for flora licences under the *Biodiversity Conservation Regulations 2018*, and on issues relating to the management of the Western Australian flora industry.
- Revised and published Corporate Guideline 36 - *Conservation of species through translocation, captive breeding and seed production areas*.
- Provided support to survey poorly-known priority flora to contribute towards conservation status assessment.

### Management implications

- Accurate, contemporary and comprehensive lists of threatened and priority flora facilitate improved environmental impact assessments, and development of more effective conservation and recovery actions.
- Provision of accurate and up to date scientific information helps to guide threatened flora recovery plans and recovery teams, improves the effectiveness of conservation activities and maximises recovery outcomes.
- Provision of expert technical and management advice on applications to take threatened or priority flora, and for environmental impact assessment, assists the department and other land managers to conserve threatened and priority flora and maximises the potential for positive conservation outcomes.

### Future directions

- Continue to deliver strategic direction and coordination for conservation, management, protection and recovery of flora in an efficient and effective manner.
- Continue to assess the conservation status of native flora species and prepare nominations for listing and recovery plans where necessary.
- Continue to prepare high quality technical flora advice to stakeholders as required.
- Continue to implement BC Act requirements related to native flora, and ensure processes and guidelines are in place as required.

## Fauna conservation and recovery

CF 2023-018

F Carpenter, R Harvey, N Palmer, L Povh, A Raycraft, J Richards, K Schell

### Context

Fauna is listed as threatened under the *Biodiversity Conservation Act 2016* (BC Act) when it is at risk of extinction in the wild and the BC Act provides a number of statutory mechanisms to conserve and recover threatened, specially protected and other native animal species. The department has obligations under the *Animal Welfare Act* 2002 (AW Act) to ensure requirements for ethical consideration of animals in departmental research and management activities which are achieved through the administration of an Animal Ethics Committee (AEC) and associated reporting. Provision of expert scientific advice to guide the application of statutory conservation and management planning, regulation and on-ground implementation, improves conservation outcomes for the State's fauna.

### Aims

- Provide up to date scientific advice for the management, protection and recovery of threatened and priority fauna.
- Ensure that recovery programs for threatened fauna species, including translocations, are evidence-based and effective.
- Inform policy and strategic direction relating to fauna using up-to-date science.
- Ensure that management requirements for harvest quotas and reporting of the commercial harvest of kangaroos in WA are met.
- Ensure that animals used for scientific purposes are cared for and used in an ethical and humane manner and that the department meets its commitments under the AW Act and the Australian Code for the Care and Use of Animals for Scientific Purposes.

### Progress

- Advice and support were provided to internal and external stakeholders on recovery actions for threatened fauna species, land management activities to support conservation, and national recovery plans.
- Advice and support were provided to 17 State fauna recovery teams to ensure continued conservation and recovery of threatened species, and to the national recovery teams for mala, malleefowl and bilby.

- Supported Wildlife Protection Branch by providing expert technical advice on applications for fauna licences under the *Biodiversity Conservation Regulations 2018*.
- Reviewed and provided recommendations on 19 proposals for intra- and interstate translocations involving 17 threatened and two priority fauna species, and including three captures into, and four releases from, captive-breeding programs.
- Provided the annual report on the commercial harvest of kangaroos in WA in 2022 to the Australian Government and drafted the Management Plan for the Commercial Harvest of Kangaroos in Western Australia 2024-2028.
- The AEC met six times, conducted a total of 345 assessments, approved 11 new projects and approved the renewal of 19 projects. There are129 active AEC approved projects for fauna monitoring, general fauna research, translocations, fauna surveys, education, feral animal control research and marine research.

**Management implications**

- Provision of accurate and up to date scientific information helps to guide threatened fauna recovery plans and recovery teams, improves the effectiveness of conservation actions, and maximises recovery outcomes.
- Expert assessment of fauna translocation plans, and provision of technical and management advice on translocations, minimises animal welfare risks and optimises translocation success.
- Assessment of kangaroo population dynamics ensures that commercial harvesting continues at a sustainable level.
- Ensuring that fauna management activities are formally assessed by the departmental AEC, and conducted in accordance with Standard Operating Procedures, fulfills legislative requirements of the AW Act.

**Future directions**

- Continue to deliver strategic direction and coordination of the conservation, management, protection and recovery of fauna in an efficient and effective manner.
- Continue to ensure that the correct processes and advice are in place for the department to meet its requirements under the AW Act.
- Continue to implement BC Act requirements related to native fauna, and ensure processes and guidelines are in place as required.

## Conservation and recovery of threatened ecological communities

CF 2023-016

V English, R Harvey, R Luu, K Schell, A Wisolith

**Context**

Ecological communities are listed as threatened under the *Biodiversity Conservation Act 2016* (BC Act) when they are at risk of collapse and the BC Act provides a number of statutory mechanisms to conserve and recover threatened ecological communities. Provision of expert scientific advice to guide the application of statutory conservation and management planning, regulation and on-ground implementation, improves conservation outcomes for ecological communities around the State.

**Aims**

- Develop, test and review threatened ecological community (TEC) identification and monitoring techniques to ensure guideline is kept up to date with current scientific knowledge and environmental impact assessments (EIAs) are based on correct identification of TECs.
- Document and describe ecological communities eligible for listing as priority ecological communities (PECs) and TECs.
- Coordinate the preparation of and prepare recovery plans for TECs.
- Contribute to combined listing and conservation advice led by the Commonwealth government.

- Provide scientific knowledge to guide development of effective mitigation strategies for management of threats acting on terrestrial, aquatic, estuarine and marine ecosystems, and contribute to regional conservation planning with scientific knowledge.
- Leverage opportunities for stakeholder involvement in recovery planning and recovery teams.
- Provide advice to land managers on appropriate fire management strategies.

**Progress**

- The first listing of ecological communities under the Western Australian *Biodiversity Conservation Act 2016* (BC Act) was gazetted.
- As at 30 June 2023, there were 65 TECs (45 critically endangered, 9 endangered and 11 vulnerable). Another 390 ecological communities are recognised as Priority Ecological Communities.
- Two meetings of the Threatened Ecological Communities Scientific Committee were held that finalised comments on assessments of the TECs using the International Union for Conservation of Nature Red List for Ecosystems categories and criteria.
- A six week stakeholder consultation process for TEC occurrences included notification to private landholders, mineral tenement holders, pastoral lease holders, government agencies, and Native Title holders and Indigenous Protected Area Body Corporates of TEC occurrences on their land.
- The document *Methods for survey and identification of Western Australian threatened ecological communities* was published, providing further detailed information about floristic community types on the southern Swan Coastal Plain.
- Detailed scientific and technical information was provided to the Commonwealth government to inform listing decisions under the *Environment Protection and Biodiversity Conservation Act 1999*.

**Management implications**

- Provision of accurate and up to date scientific information helps to guide TEC recovery plans and recovery teams, improves the effectiveness of conservation actions and maximises recovery outcomes.
- Listing of TECs and PECs means they are given priority consideration when planning and carrying out activities including the management of weeds, pests, diseases, fire, hydrology and visitor access, with the aim of protecting them, restoring their values and decreasing their vulnerability to threatening processes.

**Future directions**

- Pursue improvements in TEC and PEC knowledge, and migrate data into the new corporate database.
- Continue to provide data and advice for the protection, conservation and management of TECs and PECs.
- Continue to implement BC Act requirements related to ecological communities, and ensure processes and guidelines are in place as required.

## Assessment and advice for conservation significant species and ecological communities

CF 2023-014

C Bourke, R Boyland, A Connell, K Griffiths, R Harvey, T Johnston, R Luu, R Rees, B Richards

**Context**

The *Biodiversity Conservation Act 2016* (BC Act), the *Environmental Protection Act 1986* and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* provide legislative mechanisms for the protection of threatened species and ecological communities. Decisions for Ministerial authorisation to take or disturb threatened species or modify an occurrence of a ecological community require detailed understanding of the risks posed to the conservation of threatened biodiversity by these actions and cumulatively across all sources of impact. Assessing these risks, requires the application of specialist technical knowledge and consideration of up-to-date scientific information.

### Aims

- Effectively translate and communicate scientific knowledge and information to decision makers and managers through appropriate processes.
- Develop and maintain digital processes for administering authorisations under sections 40 and 45 of the BC Act.
- Evaluate applications to take threatened species and modify threatened ecological communities under sections 40 and 45 of the BC Act.
- Provide advice to the Department of Water and Environmental Regulation and the Department of Mines, Industry Regulation and Safety for decisions under the *Environmental Protection Act 1986*. This includes ensuring conditions and offsets are appropriate, aligned and based on best available scientific knowledge.
- Provide advice internally within DBCA to the Land Use Planning and Environmental Management branches.
- Publish and maintain public-facing guidelines, procedures and compliance documents to inform proponents regarding application processes

### Progress

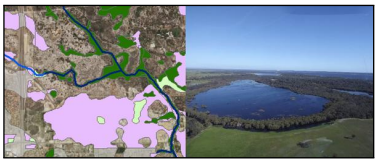
- Under section 40 of the BC Act there were 290 authorisations issued for threatened fauna and 175 authorisations issued for threatened flora. One authorisation to modify a threatened ecological community was issued after their gazettal on 26 May 2023.
- Advice was provided on risks to the conservation of threatened species, threatened ecological communities and wetlands to inform regulatory processes for key State Government initiatives and major resource developments of economic importance to WA, including the Ord Irrigation Area, bauxite mining expansion, lithium mining and processing, salt and potash, hydrogen and renewable energy, oil and gas developments, and major infrastructure including Metronet, the Morley to Ellenbrook Line, Mitchell Freeway and Tonkin Highway extensions, Bunbury Outer and Albany Ring roads.
- Corporate Guideline No. 37 *Assessing risks to the conservation of biodiversity associated with threatened species and threatened ecological communities* was published and made available to other decision makers and proponents to improve consistency in advice and decision making.

### Management implications

- Standardised assessment of risks to threatened species and ecological communities provides a clear and transparent process for authorising take whilst providing for the conservation of biodiversity.
- New assessment processes contribute to the delivery of Streamline WA initiatives and ongoing approvals reform by providing advice to decision-making authorities that is targeted, effective, and timely.

### Future directions

- Develop further guidance for proponents and other decision makers to improve decision making for key species and ecological communities that are frequently impacted by proposals.
- Improve engagement with other government agencies and stakeholders to assist in communicating the standard risk assessment and changes to regulatory requirements since BC Act implementation.



## Wetland mapping

CF 2023-013

F Felton, R Harvey, J Donaldson

### Context

Western Australia is home to many different varieties of wetlands, from tidal mangroves and billabongs, to salt lakes and fresh water springs. Access to accurate geospatial and ecological information about wetlands improves the basis for informed decisions on the management and conservation of wetlands. The department coordinates mapping of Western Australia's wetlands and maintains digital datasets containing spatial data and associated attribution. The mapping identifies the presence of wetlands, delineates boundaries, classification and assigns the wetland to a management category on the basis of its values. This mapping ensures accurate

information about wetlands is available to land managers and decision makers, improving the basis for informed decision making about wetland management and conservation.

**Aims**

- Maintain current datasets and, where opportunities arise, expand the extent of wetland mapping for Western Australia.
- Maintain and improve documentation to standardise wetland mapping procedures.
- Use contemporary ecological and hydrological scientific information to continuously improve policies and methodology supporting the wetlands datasets.
- Provide input to, and assist with, the development of national wetland mapping guidelines and the Australian Wetland Inventory.
- Assist in the development of strategic policy for the conservation of high ecological value wetlands.
- Provide advice on wetland mapping and values to stakeholders in a timely manner.

**Progress**

- Reviewed four requests to modify wetland evaluation, and two requests to modify wetland delineation in the *Geomorphic Wetland Swan Coastal Plain* dataset.
- Provided technical advice for 51 requests relating to wetland mapping, land use planning and general wetlands matters to departmental staff, other State and Commonwealth agencies, landowners, and consultants.
- Engaged with other State, Territory and Commonwealth management agencies in relation to national wetland mapping guidelines.
- Undertook wetland mapping for Badimia conservation reserves.

**Management implications**

- Accurate wetland mapping facilitates better conservation, protection and management outcomes for wetlands and wetland ecosystems by improving the evidence base for environmental impact assessment, prioritising management actions and land acquisition, and assisting with identifying suitable habitat for conservation significant species.

**Future directions**

- Continue to review and maintain wetland mapping and provide technical advice on wetlands values to internal and external stakeholders.
- Continue to review wetlands policy and procedure documentation to support the development of contemporary wetlands policy.
- Undertake wetland mapping for the Badimia conservation reserves.

# External Partnerships

| Partners | Project Title | External Funding | Departmental Involvement |
|---|---|---|---|
| Alcoa | Quantifying responses of forest thinning and developing social license to build adaptive capacity in forest management | $166,600 | K Ruthrof, R Van Dongen, G McGrath |
| Astron Environmental Services | Developing a non-invasive monitoring approach for Barrow Island boodies (*Bettongia lesueur*) | $27,204 | K Ottewell, R Shaw |
| Atlas Iron, Fortescue Metals Group, Iron Ore Holdings, Roy Hill, Main Roads Western Australia | Ecology and management of the northern quoll in the Pilbara | $195,000 | L Gibson |
| Atlas Iron, Main Roads Western Australia | Ecology and management of the Pilbara olive python | $125,000 | D Pearson, L Gibson, M Cowan |
| Atlas Iron, Rio Tinto, BHP, Kanyirninpa Jukurrpa, BatCall WA | Ecology and management of the Pilbara leaf-nosed bat | $320,000 | L Gibson, K Ottewell, L Umbrello |
| AusSeaBed Geoscience Australia | Facilitating collaborations between AusSeabed and Kimberley Region marine operations by crowd sourcing bathymetry to improve national bathymetry data | Nil | K Murray, W Robbins, K Zdunic |

| Partners | Project Title | External Funding | Departmental Involvement |
|---|---|---|---|
| Australian Biological Resources Study, Queensland Herbarium, Northern Territory Herbarium, University of the Western Cape (South Africa) | Towards an eFlora treatment of *Tephrosia* (Pers.) in Australia: taxonomic revision of the genus in Western Australia and the Northern Territory | $515,000 | T Macfarlane |
| Australian Institute of Marine Science, CSIRO | Mapping flatback turtle foraging areas in the Kimberley | $1,000,000 | S Whiting, S Fossette-Halot, T Tucker |
| Australian Research Council, Australian National University, University of Adelaide, Australian Museum, Western Australian Museum | Island genomes: enhancing management of Australia's threatened mammals | $460,000 | K Ottewell, M Byrne |
| Australian Research Council, Charles Darwin University, Save the Gouldian Fund, Ballanggarra Aboriginal Corporation, World Wide Fund for Nature, Wild Spy Pty Ltd, National Drones Pty Ltd, The University of Auckland, Kimberley Land Council | Movement ecology of granivores: informing fire management of savannas | $400,000 | I Radford |
| Australian Research Council, Flinders University, CSIRO, The University of Western Australia | Optimising seed sourcing for effective ecological restoration | $460,000 | S Krauss, D Merritt |
| Australian Research Council, Murdoch University, Western Australian Museum, Roy Hill | Building resilience to change for mammals in a multi-use landscape | $536,000 | K Ottewell, L Gibson, M Byrne, R Shaw |
| Australian Research Council, Murdoch University | Optimising fire regimes for fire risk and conservation outcomes in *Banksia* woodlands in the Perth area | $455,000 | B Miller, R Miller, K Ruthrof |
| Australian Research Council, The University of Western Australia, Australian National University | The evolution and conservation consequences of promiscuity in plants pollinated by vertebrates | $1,400,000 | S Krauss |

| Partners | Project Title | External Funding | Departmental Involvement |
|---|---|---|---|
| Australian Research Council, The University of Western Australia, University of Adelaide, Australian Genome Research Facility | Seagrass adaptation and acclimation responses to extreme climatic events | $525,000 | S Krauss |
| Australian Research Council, University of Queensland, The University of Western Australia | Assessing the ecosystem-wide risks of threatened species translocation | $311,377 | M Byrne |
| Australian Research Council, University of Sydney, Department of the Environment and Energy, Australian Reptile Park | Predicting the ecological impact of cane toads on native fauna of north western Australia | $503,000 | D Pearson |
| Australian Research Council | Beyond fire frequency: understanding seasonal timing of fire for ecosystem management | $453,000 | B Miller, K Ruthrof |
| BHP Iron Ore Pty Ltd | Spatial and temporal analysis of ghost bat populations in the Pilbara using non-invasive sampling methodologies: Towards a robust genetic monitoring protocol | $190,000 | K Ottewell, R Sun, D Prada, S McArthur |
| BHP, CyMod Systems, Australian Nuclear Science and Technology Organisation | Hydrogeochemistry of Walyarta Springs | $120,000 | J Rutherford |
| BHP, Department of Primary Industries and Regional Development, Department of Water and Environmental Regulation, Fortescue Metals Group, Precision Biomonitoring, Rio Tinto, Stantec | Redclaw crayfish impact assessment and eDNA detection tool | $475,000 | A Pinder |
| BioPlatforms Australia, Centre for Biodiversity Analysis, Western Australian Museum, Australian Museum, South Australia Museum, Museum of Victoria, University of Adelaide | Oz Mammals Genomics | $1,112,000 | M Byrne, K Ottewell |

| Partners | Project Title | External Funding | Departmental Involvement |
|---|---|---|---|
| BioPlatforms Australia, Ian Potter Foundation, Royal Botanic Gardens Victoria, Centre for Australian Plant Diversity Research, Australian Tropical Herbarium, Royal Botanic Gardens and Domain Trust, Southern Cross University | Genomics for Australian plants | $1,800,000 | M Byrne, S Krauss |
| BioPlatforms Australia: Threatened Species Initiative | Threatened Species Initiative | N/A | K Ottewell |
| CSIRO Environment, Floreat W.A. | Understanding 3D landscapes to manage ecosystem water, carbon and water quality. | Nil | J Rutherford |
| CSIRO Future Science Fellowships in Environomics | Lifespan estimation in marine turtles using genomic promoter CpG density | $310,000 | T Tucker, S Whiting |
| CSIRO, Australian SuperSite Network, Terrestrial Ecosystem Research Network, National Research Infrastructure for Australia | Great Western Woodlands SuperSite | Nil | C Gosper |
| CSIRO, National Environmental Science Program - Marine Biodiversity Hub | Dugong population and habitat survey - Shark Bay and Ningaloo | $123,622 | H Raudino, K Waples, K Murray |
| CSIRO, National Environmental Science Program - Threatened Species Recovery Hub, Australian Wildlife Conservancy, Bush Heritage Australia, Department of the Environment and Energy | Explaining and predicting the occurrence of night parrots (*Pezoporus occidentalis*) using GIS and ecological modelling | $38,000 | A Burbidge |
| CSIRO, Ngadju Conservation Aboriginal Corporation, University of Bristol | Mapping of mature woodlands in Ngadju lands for fire management | $265,000 | C Gosper, K Zdunic, G Page |
| CSIRO, The University of Western Australia | Marine turtle stable isotopes | Nil | T Tucker, S Whiting |

| Partners | Project Title | External Funding | Departmental Involvement |
|---|---|---|---|
| CSIRO, Woodside | Great Western Woodlands carbon methodology | $315,000 | C Gosper, K Zdunic |
| Chevron - Wheatstone | Conserving critical seagrass habitat for dugong: an integrated assessment across the Pilbara | $1,236,754 | K Waples, H Raudino |
| Chevron | Translocations of mammals from Barrow Island: offset program | $9,500,000 | C Sims, J Angus, S Garretson, L Gibson |
| Conceptual population model and knowledge gaps for little penguin colonies in Western Australia | Conceptual population model and knowledge gaps for little penguin colonies in Western Australia | $18,000 | T Holmes, I Leal, S Wilson |
| Curtin University, Australian Institute of Marine Science, The University of Western Australia, Department of Primary Industry and Regional Development, Flinders University, Department of Environment and Water (SA), Deakin University, Department of Primary Industries (NSW), University of Tasmania, CSIRO, FinPrint | Australian wide synthesis of baited video data to answer broad-scale ecological questions | Nil | T Holmes, J Goetze |
| Curtin University, Trend Laboratory | Detection and identification of dugong through seawater eDNA | $40,000 | W Robbins |
| Curtin University, The University of Western Australia, Society for Ecological Restoration Australasia, BHP, Sinosteel Midwest Corporation, Mineral Resources, Hanson Construction Materials, Karara Mining Limited | ARC Training Centre for Mining Restoration | $4,961,622 | D Merritt, S Krauss, J Stevens |
| Department of Fire and Emergency Services, Bushfire Front | Karri forest fuel dynamics | Nil | V Densmore, A Wills, S Samson, J Hollis |
| Department of Fire and Emergency Services | Fire severity and dense forest stands | $50,000 | K Ruthrof, R Van Dongen, V Densmore |

| Partners | Project Title | External Funding | Departmental Involvement |
|---|---|---|---|
| Department of Jobs, Tourism, Science and Innovation Marine Heatwaves Group | Advancing observations and predictions of WA marine heatwaves | $500,000 | C Ross |
| Department of Organismal Biology and Ecology, Colorado College (USA), St John University (USA) | Phylogenetics and floral symmetry development of the core Goodeniaceae | Nil | K Shepherd |
| Department of Primary Industries and Regional Development, CSIRO, Australian Institute of Marine Science, Curtin University | Connectivity of coral trout populations between individual reefs on the Rowley Shoals | Nil | R Evans |
| Department of Primary Industries and Regional Development | Developing novel remote camera approaches to assess and monitor the population status of Australian sea lions | Nil | H Raudino, K Waples |
| Department of Water and Environment Regulation | Geographe Bay seagrass satellite mapping | $60,000 | S Bell, K Murray |
| Department of Water and Environmental Regulation, Water Corporation | Millstream riparian vegetation monitoring | $2000 | B Huntley |
| Department of Water and Environmental Regulation | Swan Canning Estuary microplastics and plastics survey | $75,000 | P Novak, K Trayler |
| Department of the Environment and Energy | Western Australian black spot biological survey campaign | $170,000 | A Pinder, M Lyons, M Cowan |
| Duke University, Swedish University of Agricultural Sciences, University of Helsinki | Lifeplan: A Planetary Inventory of Life | $30,000 | A Pinder, A Barrett, K Quinlan, G Barrett, R Glowicki, M Brotherson |
| Ecological Horizons, Fortescue Metals Group, Roy Hill | Testing the efficiency and efficacy of Felixer feral cat grooming traps | $85,000 | L Gibson |
| Edith Cowan University, Australian Museum Research Institute | Diversity of infaunal polychaete assemblages in Walpole and Nornalup Inlets Marine Park | Nil | I Leal, S Wilson |

| Partners | Project Title | External Funding | Departmental Involvement |
|---|---|---|---|
| Edith Cowan University, University of Western Australia, Australian National University, Department of Primary Industries and Regional Development | Australian sea lions in the Perth metropolitan area: abundance, movement and habitat use. | $264,803 | K Waples, H Raudino |
| Edith Cowan University | WAMSI-Westport seagrass project | $1,200,000 | S Strydom |
| European Centre for Medium Range Weather Forecasting, Reading, UK | Using machine learning to predict fire ignition occurrences from lightning forecasts | Nil | L Mccaw |
| Florida International University, Australian Institute of Marine Science, James Cook University | Global FinPrint | Nil | J Goetze |
| Fortescue Metals Group, Millennium Minerals, Roy Hill | Ecology and management of the bilby in the Pilbara | $2,005,000 | M Dziminski, F Carpenter |
| Fremantle Ports | Fremantle Marine Quality Monitoring Program | $30,659 | S Hoeksema, K Trayler |
| Genomics for Australian Plants | Phylogenomics of the Western Australian flora | - | B Anderson |
| Geocatch, Edith Cowan University, Department of Primary Industries and Regional Development | The long-term monitoring of seagrass communities in Geographe Bay | $10,000 | B French |
| Gilbert's Potoroo Action Group and State NRM | Population genomics of the Critically Endangered Gilbert's Potoroo | $35,000 | K Ottewell, M Millar, R Sun, T Friend |
| Global Peat Microbiome Project (GPMP) | Peatland resilience - Global Peat Microbiome Project | Nil | J Rutherford |
| Great Western Woodlands fire history update and data quality improvement. | Great Western Woodlands fire history update and data quality improvement. | 29,813 | K Zdunic, J Ruscalleda Alvarez |
| Hannah Cliff and Gareth Catt, Indigenous Desert Alliance | Impact of prescribed fire on desert fire regimes | Nil | V Densmore, J Chapman |
| Hanson Construction Materials | Restoring *Banksia* Woodland communities after mining | $25,000 pa | J Stevens, W Lewandrowski |

| Partners | Project Title | External Funding | Departmental Involvement |
|---|---|---|---|
| Landscape SA and South Australian Research and Development Institute | Prioritising onground actions for the endangered Australian sea lion | $32,600 | K Waples, H Raudino |
| Main Roads Western Australia, Kimberley Land Council, Rangelands NRM Western Australia, Nyamba Buru Yawuru Ltd, Walalakoo Aboriginal Corporation, Bardi Jawi Aboriginal Corporation | Conservation and management of the bilby (*Macrotis lagotis*) on the Dampier Peninsula, Kimberley | $600,000 | M Dziminski, R McPhail, F Carpenter |
| Margaret River Busselton Tourist Association Inc, Curtin University | Characterising organic carbon sources supporting cave pool communities in the Leeuwin Naturaliste Ridge | $10,000 | M Venarsky, G McGrath |
| Millennium Seed Bank, Australian Seed Bank Partnership, Department of the Environment and Energy | Seed collection, storage and biology | $12,000 | A Crawford |
| Mineral Resources Ltd, The University of Western Australia | Integrated conservation and translocation of the threatened banded ironstone species *Tetratheca erubescens* (Elaeocarpaceae) | $997,000 | J Stevens, B Miller, S Krauss, D Merritt, W Lewandrowski, C Elliott |
| Murdoch University | Radio Frequency Identification devices as a new method to estimate Little Penguins population size: Penguin Island as case-study | Nil | T Holmes, I Leal |
| Murdoch University | Collation of historic data for Shark Bay, Marmion and Shoalwater Islands Marine Parks. | $20,000 | J Goetze |
| Murdoch University | Baseline microbial surveys in Swan Canning | Nil | K Trayler, S Hoeksema |
| Murdoch University | Using Unmanned Aerial Vehicles (UAVs) to investigate visual detection probability of coastal dolphins during aerial surveys | $115,757 | K Waples, H Raudino |

| Partners | Project Title | External Funding | Departmental Involvement |
|---|---|---|---|
| Murdoch University | Genetic studies of Pilbara EPBC Act listed threatened vertebrate fauna | $235,000 | D Pearson, M Cowan |
| NSW Rural Fire Service | A new National Fire Danger Rating System for Australia | Nil | L Mccaw |
| National Environmental Science Program - Northern Australia Environmental Resources Hub, Environs Kimberley, Kimberley Land Council | Securing the future for bilby in the Fitzroy Catchment / West Kimberley | $540,000 | M Dziminski, R McPhail, F Carpenter |
| National Environmental Science Program - Resilient Landscapes Hub; University of Western Australia; Perth NRM; Armadale Gosnells Landcare Group | Enhancing the resilience of urban rivers: informing the regional restoration of the Djarlgaroo Beeliar Canning River, Perth) | Nil | |
| National Environmental Science Program 2 - Marine and Coastal Hub, Reef and Rainforest Research Centre | A partnership approach to filling key knowledge gaps on dugongs in northern Australia using novel technologies | $379,366 | H Raudino, K Crook, K Waples |
| National Science Foundation (USA) | Systematics and biogeography of the Inocybaceae | $19,000 | N Bougher |
| Net Conservation Benefits, CSIRO | Molecular characterisation of stinking passionflower (*Passiflora foetida*) | $913,000 | M Byrne |
| Peel Harvey Catchment Council | Understanding sources of feral cats in Dryandra Woodland through DNA analysis | $20,000 | K Ottewell, R Shaw |
| R.J. Shiel and Associates | Aquatic microinvertebrate identification and systematics | $5000 | A Pinder, K Quinlan, D Cale |
| Rio Tinto Iron Ore | *Aluta quadrata* plant water use and niche characteristics | $306.382 | W Lewandrowski, J Stevens |
| Rio Tinto, BHP | Seed collection zones for the Pilbara | $450,000 | M Byrne, R Binks |

| Partners | Project Title | External Funding | Departmental Involvement |
|---|---|---|---|
| Rio Tinto, GHD | A morphological and molecular investigation to resolve the taxonomic status of *Rhagodia* sp. Hamersley from the Pilbara bioregion | $59,000 | B Anderson, R Binks |
| Rio Tinto | Genetic diversity and population structuring of *Tetratheca butcheriana* in the Pilbara bioregion of Western Australia | $97,000 | M Byrne, J Filipe, R Binks |
| 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 | M Byrne, R Binks |
| Royal Botanic Gardens - Kew, University of Portsmouth (UK) | The *Stylidium* phylogeny and pollination project | Nil | J Wege |
| SCORE-REEF | Spatio-temporal variability of coral reefs at the global scale: causalities, idiosyncrasies and implications for ecological indicators | Nil | S Wilson, T Holmes, J Goetze, C Ross |
| The University of Western Australia, National Marine Fisheries Service (USA), Northern Territory Museum, Western Australian Museum, Queensland Department of Environment and Science, Pendoley Environmental, Australia Government Department of Agriculture, Water and Environment | Skeletochronology and stable isotope analyses of flatback turtles | $400,000 | T Tucker, S Whiting |
| The University of Western Australia | Susceptibility of frogs to declining rainfall in a biodiversity hotspot | Nil | M Cowan |

| Partners | Project Title | External Funding | Departmental Involvement |
|---|---|---|---|
| The University of Western Australia | Assessing the vulnerability of honey possums to climate change and habitat disturbances in south-western Australia | Nil | M Cowan |
| Threatened Species Initiative (plants) | Threatened Species Initiative (plants) | Nil | A Crawford, L Monks, R Binks, M Byrne |
| University of Aukland, Macquarie University, University of Western Australia | Mirnong Maat (whale journeys) – Southern Right Whale research project | Nil | K Waples, H Raudino, S Bell |
| 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 New South Wales, Western Sydney University, Royal Botanic Gardens and Domain Trust etc | AusTraits: a national database on the traits of Australia's complete flora | $500,000 | C Gosper |
| University of Queensland | Development of a male dibbler and numbat fertility index through the evaluation of spermatorrhoea characteristics to determine if there is a male factor in breeding success | Nil | P Mawson |
| University of Western Australia | Long-term monitoring of intertidal communities at limestone and granite reefs in Ngari Capes Marine Park | $5,000 | S Bell, I Leal |
| WWF-Australia and Western Australian Government's State NRM Program | A Population Management Plan for the Wheatbelt Black-flanked Rock Wallaby | $10,450 | L Povh, K Ottewell, K Nilsson, M Dziminski, A Raycraft |

# Student Projects

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| R Binks | G Carey (MSc) | Dr W Webb (University of Western Australia), A Lullfitz (University of Western Australia), Prof S Hopper (The University of Western Australia) | Phylogeographic analysis for Kalloora conservation management in the South-Western Australian Floristic Region | 2022 – 2023 | 149 |
| B Funnekotter, E Bunn | L Whelehan (PhD) | Prof R Mancera (Curtin University) | Characterisation of mitochondrial function in the cryopreservation of threatened flora | 2019 – 2024 | 149 |
| B Funnekotter, E Bunn | L Hardstaff (PhD) | Prof R Mancera (Curtin University) | Conservation of Australian rainforest plant species utilising cryopreservation | 2018 – 2023 | 150 |
| B Funnekotter, E Bunn | M Lukic (PhD) | Prof R Mancera (Curtin University) | Role of redox homeostasis in recovery from cryopreservation in *Arabidopsis thaliana* | 2020 – 2023 | 150 |
| B Funnekotter, E Bunn | L Hou (MSc) | Prof R Mancera (Curtin University) | Development of cryopreservation for the recalcitrant seeded Australian plants *Syzygium australe* and *S. paniculatum* | 2020 – 2020 | 150 |

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| A Burbidge | N Leseberg (PhD) | A/Prof R Fuller (University of Queensland), Dr S Murphy (Australian National University), Dr J Watson (University of Queensland) | Ecology and conservation biology of the night parrot | 2017 – 2019 | 151 |
| M Byrne | B Nordstrom (PhD) | A/Prof N Mitchell (The University of Western Australia), S Jarman (The University of Western Australia) | Assisted colonisation of the western swamp tortoise (*Pseudemydura umbrina*): the role of energy requirements in translocation decisions | 2020 – 2024 | 151 |
| M Byrne | R Dillon (PhD) | Prof M Waycott, Dr R Standish (The University of Western Australia) | Mating systems, reproductive output and progeny fitness of translocated plant populations compared to wild populations | 2017 – 2020 | 152 |
| M Byrne | L Monks (PhD) | Dr R Standish (The University of Western Australia), D Coates | Factors affecting the success of threatened flora translocations | 2016 – 2020 | 152 |
| J Cosgrove | S Kwambai (PhD) | Dr D Laird (Murdoch University), A/Prof N Moheimani (Murdoch University), A/Prof A Lymbery (Murdoch University) | *Alexandrium* spp. in Western Australia: characterisation, toxin mobility and control options | 2021 – 2024 | 153 |
| J Cosgrove | M Jung (PhD) | Dr M Fraser (The University of Western Australia), Dr B Martin (The University of Western Australia), Prof. G Kendrick (University of Western Australia) | Tracking seagrass condition: development and application of novel molecular biomarkers | 2020 – 2023 | 153 |
| A Burbidge, S Cowen | A Gibson Vega (PhD) | Associate Prof. A Ridley (University of Western Australia), Dr J Kennington (The University of Western Australia) | Genetic characterisation and behavioural ecology of the western grasswren (*Amytornis textilis*) | 2019 – 2022 | 153 |
| S Cowen, C Sims | Dr F Knox (PhD) | Dr R Vaughan-Higgins (Murdoch University), A/Prof K Warren (Murdoch University) | Dirk Hartog Island fauna reintroductions disease risk analysis | 2019 – 2022 | 154 |

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| S Cowen | R Quah (MSc) | Dr D White (University of Western Australia) | Conservation genetics and population modelling to secure wild populations of the Shark Bay mouse (*Pseudomys fieldi*) | 2020 – 2021 | 154 |
| S Cowen | R Stover (MSc) | Dr A Hopkins (Edith Cowan University), Dr R Davis (Edith Cowan University), Dr H Mills (The University of Western Australia) | Comparative analysis of diet in island populations of banded and rufous hare-wallabies in Shark Bay | 2021 – 2022 | 154 |
| S Fossette-Halot | J Hounslow (PhD) | Dr A Gleiss (Murdoch University) | Ecology of flatback turtles (*Natator depressus*) at a coastal foraging ground, Western Australia | 2019 – 2025 | 155 |
| S Fossette-Halot, S Whiting | C Avenant (PhD) | A/Prof G Hyndes (Edith Cowan University) | Understanding predator-prey interactions between ghost crabs and marine turtles for better management of an endangered species | 2019 – 2023 | 155 |
| S Fossette-Halot | M Gammon (PhD) | A/Prof N Mitchell (The University of Western Australia) | Predicting the vulnerability of flatback turtle rookeries to a changing climate | 2018 – 2023 | 156 |
| L Gibson | M Cowan (PhD) | A/Prof D Nimmo (Charles Sturt University), A/Prof S Setterfield (University of Western Australia) | The influence of mining on the movement ecology and behaviour of the endangered northern quoll (*Dasyurus hallucatus*) | 2022 – 2025 | 156 |
| J Hyde, S Thompson | E Stevens (MSc) | Dr L Beesley (The University of Western Australia), Dr D Gleeson (The University of Western Australia) | Environmental DNA as a tool to monitor fish movement in the Canning River | 2021 – 2021 | 156 |
| S Krauss, J Stevens | B Mirfakhraei (PhD) | Dr E Veneklaas (The University of Western Australia) | A genecological assessment of seed sourcing strategies for plant community restoration under environmental change | 2017 – 2020 | 157 |
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| D Merritt | S Henningsen (PhD) | T Erickson (The University of Western Australia) | Ecophysiology of seed dormancy of *Hibbertia* | 2022 – 2025 | 159 |
| B Miller | E Cowan (PhD) | Dr J Fontaine (Murdoch University), Dr R Standish (Murdoch University) | Assessing ecological resilience of post-mining restoration: testing fire recovery across a restoration chronosequence | 2019 – 2022 | 159 |
| B Miller, K Ruthrof | A Brace (PhD) | Dr A Hopkins (Edith Cowan University), Dr J Fontaine (Murdoch University) | Shifting soil fungal communities in response to fire and weed management in urban banksia woodlands | 2019 – 2023 | 159 |
| B Miller, D Merritt | R Miller (PhD) | Dr J Fontaine (Murdoch University), Prof N Enright (Murdoch University) | Ecologically tolerable fire regimes for key banksia woodland plant species | 2015 – 2019 | 160 |
| P Novak | T Crutchett (PhD) | R Hovey (UWA) | Microplastic distribution, sources, ingestion and health impacts in urban estuarine environments | 2021 – 2024 | 160 |
| P Novak | M Williams (PhD) | A/prof J McIlwain (Curtin University) | Plastic pollution in urban drains | 2022 – 2022 | 161 |
| P Novak | A Gillies (PhD) | A/Prof N Callow (University of Western Australia) | Canning River water quality and macrophyte investigation | 2022 – 2022 | 161 |
| K Ottewell | R de Visser (BSc Honours) | Dr R Catullo (University of Western Australia), Dr M Hall (Bush Heritage Australia) | Landscape genetics of red-tailed phascogales in south-west WA | 2022 – 2022 | 161 |
| K Ottewell | K Rick (PhD) | A/Prof N Mitchell (University of Western Australia) | Understanding patterns of phenotypic and genetic divergence in island mammals to improve conservation outcomes | 2020 – 2023 | 162 |
| A Pinder | A Islam (PhD) | Dr J Chaplin (Murdoch University) | Taxonomy and evolutionary history of *Parartemia* brine shrimp from Australian salt lakes | 2020 – 2023 | 162 |
| A Pinder | M Rahman (PhD) | Dr J Chaplin (Murdoch University) | Taxonomy and evolutionary history of *Australocypris* giant ostracods from Australian salt lakes | 2019 – 2022 | 163 |
| A Pinder | A Lawrie (PhD) | Dr J Chaplin (Murdoch University) | Taxonomy, ecology and evolutionary history of the salt lake gastropod *Coxiella* | 2019 – 2022 | 163 |

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| H Raudino, K Waples | J Tucker (BSc Honours) | Dr C Salgado Kent (Edith Cowan University) | Extending aerial surveys beyond target marine mammal species: an application of strip transect methodology to humpback whale abundance estimation in Exmouth Gulf, WA | 2022 – 2023 | 164 |
| K Ruthrof | S Brennan (MSc) | Dr J Fontaine (Murdoch University) | Implications of ecological thinning on jarrah forest fuels and potential fire behaviour | 2023 – 2024 | 165 |
| J Stevens | S Sullivan (PhD) | A/Prof P Poot (The University of Western Australia), Dr E Veneklaas (The University of Western Australia) | The influence of drought on plant morphology, physiology and establishment in the post iron ore mining environments of semi-arid Western Australia | 2016 – 2020 | 165 |
| J Stevens | J Ruscalleda Alvarez (PhD) | Dr J Yong (The University of Western Australia), Dr E Veneklaas (The University of Western Australia) | Near-surface remote sensing of plant condition in mine site restoration environments | 2017 – 2021 | 166 |
| J Stevens | W Wong (PhD) | A/Prof R Trengove (Murdoch University), Dr J Yong (The University of Western Australia), Dr E Veneklaas (The University of Western Australia) | Soil-microbial-plant signals and effects on plant eco-physiological performance for mine site restoration | 2017 – 2021 | 166 |
| J Stevens | E Arora (PhD) | Dr A Guzzomi (The University of Western Australia), Dr S Tomlinson (Curtin University), Prof K Dixon (Curtin University) | Implications for wind management in restoration ecology, linking ecosystem aerodynamics to physiological drivers in arid and semi-arid systems | 2015 – 2019 | 167 |
| S Adiyanti | S Lim (MSc) | Dr C Pattiaratchi (The University of Western Australia) | Investigating wind and wave impacts on the Swan Estuary Marine Reserve foreshore – Nedlands | 2022 – 2023 | 167 |
| K Trayler | E Taljaard (PhD) | J Tweedley (Murdoch University) | Understanding drivers of fish communities - Eagle Rays | 2022 – 2023 | 167 |

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| A Wayne | M Taylor (PhD) | Dr M Calver (Murdoch University), Dr K Bryant (Murdoch University), Dr N Armstrong (Murdoch University) | Survey methods and population estimates of the chuditch across its range | 2020 – 2023 | 168 |
| A Wayne | W Geary (PhD) | A/Prof E Ritchie (Deakin University), A/Prof D Nimmo (Charles Sturt University), Dr T Doherty (Deakin University), Dr A Tulloch (University of Sydney) | Modelling species interactions and other environmental factors in the Upper Warren | 2019 – 2022 | 169 |
| A Wayne | S Thorn (PhD) | A/Prof N Mitchell (The University of Western Australia), Dr R Firman (The University of Western Australia) | The population and spatial ecology of the numbat in the Upper Warren | 2018 – 2021 | 169 |
| S Whiting | E Young (PhD) | Dr R Vaughan-Higgins (Murdoch University), A/Prof K Warren (Murdoch University), Dr L Yeap (Murdoch University), Dr N Stephens (Murdoch University) | The health status of marine turtles in northern and western Australia | 2016 – 2024 | 170 |
| J Hyde, G McGrath | S Thompson (MSc) | Dr A Hopkins (Edith Cowan University), Dr A Koenders (Edith Cowan University) | Chasing Flamingos - Tracking synthetic eDNA in a river network using passive sampling methods | 2022 – 2025 | 170 |

# Student Project Reports

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

STP 2016-018


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


This research is focussed on understanding feral cat spatial ecology, diet and their impacts on native species in four study sites on the south coast of Western Australia. This research will also test the effectiveness of stable isotope analysis for increasing understanding of feral cat dietary niche and impact on native species. The relationship between prey availability and climate and productivity indices will be studied in Two Peoples Bay Nature Reserve.

Strong evidence of an ongoing impact of feral cats on native mammals and passerines was found in major conservation areas and fragmented landscapes on the south coast. Both isotopic niche and mixing models validated stomach content analysis and provided insights into feral cat diet over extended time periods. Mixing models using 13C and 15N tracers provided evidence of feral cat predation on the critically endangered western ground parrot (*Pezoporus flaviventris*), which was not detected in stomach content analysis.

Feral cat habitat preferences were found to be similar to those in other areas of Australia, with moisture gaining sites and regions of high productivity important areas to target in management programs. Areas of native vegetation provided significant refuge value in fragmented landscapes. Investigations into prey availability found that climatic variables and dynamic habitat indices, derived from remote sensed data, could be used to predict small mammal trap success and available biomass. These findings provide insights that can be used to improve timing of control efforts, such as cat baiting, in an adaptive management framework.

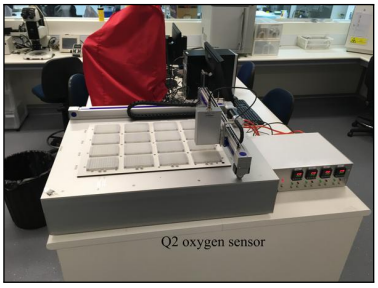
## Phylogeographic analysis for Kalloora conservation management in the South-Western Australian Floristic Region

STP 2022-021

Scientist(s): R Binks
Student: G Carey (MSc)
Academic(s): Dr W Webb (University of Western Australia), A Lullfitz (University of Western Australia), Prof S Hopper (The University of Western Australia)

This project is working with the Wadandi people of the Busselton/Margaret River region to understand the cultural significance and traditional use of the Kalloora (Emu Plum, *Podocarpus drouynianus*) in southwestern Australia. This project also includes a genetic study to assess the health and population dynamics of the species that will inform its future management and long-term preservation.

Genetic samples have been sequenced for both SNP markers and chloroplast DNA markers and the data have been analysed. Sequencing nuclear data from gymnosperms is often challenging due to their complex genomes and unfortunately, the SNP data exhibited low resolution; nevertheless, it showed a general pattern of low genetic differentiation amongst populations across the species' main distribution in the southern Jarrah forests, in contrast to the more differentiated disjunct populations located in the Swan region. This geographic pattern was consistent with that shown in the results from the chloroplast genome. In addition, the chloroplast data showed high levels of haplotype diversity within and among populations and no phylogeographic structure, indicating historically large population sizes and high gene flow, with no indication of contraction to refugia through historical climate fluctuations.



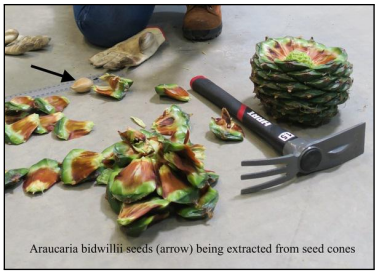

## Characterisation of mitochondrial function in the cryopreservation of threatened flora

STP 2020-066

Scientist(s): B Funnekotter, E Bunn
Student: L Whelehan (PhD)
Academic(s): Prof R Mancera (Curtin University)

This project aims to examine the effects of cryopreservation on metabolism of plant tissues, with emphasis on mitochondrial function as these organelles are the primary sources of energy molecules (ATP) that drive all cellular processes including the ability to recover from injury sustained to cells and tissues during the various steps of cryopreservation. A better understanding of the effects of cryogenic injury will enable better optimisation of cryopreservation for sensitive species, including many threatened taxa where ex situ storage remains a problem.

Trials measuring oxygen consumption of Daucus carota cells on the Seahorse XF analyser identified that certain cryoprotective agents show a significant negative effect on mitochondrial function. This work was presented at the IV International Symposium on Plant Cryopreservation. Further experiments on the viability of the Seahorse method using respiratory inhibitors to determine the specific parameters of mitochondrial function affected are in progress. The study species will be used to optimise methods for application to threatened species of native WA plants from the Kings Park tissue culture collection.


Araucaria bidwillii seeds (arrow) being extracted from seed cones

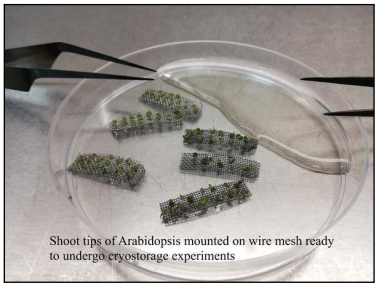
## Conservation of Australian rainforest plant species utilising cryopreservation

STP 2020-065

Scientist(s): B Funnekotter, E Bunn
Student: L Hardstaff (PhD)
Academic(s): Prof R Mancera (Curtin University)

This project has developed novel tissue culture and cryopreservation protocols for a range of recalcitrant-seeded (unable to be desiccated or stored at low temperatures) Eastern Australian rainforest taxa where conventional ex situ seed storage is not possible.

The successful development of in vitro cultures of threatened recalcitrant seeded species in several genera (*Gossia*, *Macadamia*, *Rhodamnia*, *Rhodomyrtus* and *Syzygium*) has been achieved and cryopreservation protocols are being developed with shoot tips of these species (including incl. *S. paniculatum*) and embryonic axes of *Araucaria bidwillii*. Collection and analysis of data is complete and writing is underway.


Shoot tips of Arabidopsis mounted on wire mesh ready to undergo cryostorage experiments

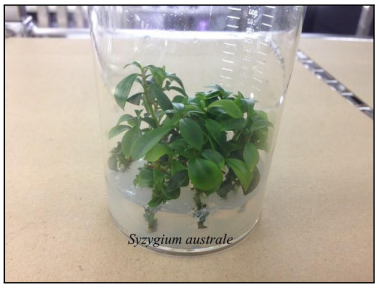
## Role of redox homeostasis in recovery from cryopreservation in *Arabidopsis thaliana*

STP 2020-064

Scientist(s): B Funnekotter, E Bunn
Student: M Lukic (PhD)
Academic(s): Prof R Mancera (Curtin University)

This project examines the effects of oxidative stress on cryopreserved plant material, using the model species *Arabidopsis thaliana*, including mutant variants with reduced antioxidant contents. Oxidative stress is a primary impediment to successful cryopreservation of plant material, and a better understanding of this will be a crucial step forward in designing more efficient cryopreservation protocols for ex-situ conservation of threatened plant species.

An optimised cryopreservation method for wild type *A. thaliana* has been developed using vitamin C- and GSH-deficient mutant plants (vtc2-1, vtc2-4, pad2-1 and cad2), to assess changes in transcriptome using RNA-seq. Assessments of the transcriptome, gene expression by RT-qPRC, oxidized DNA damage and antioxidant contents have been completed to understand the stresses imposed by cryopreservation. All experiments are completed and writing is underway.


*Syzygium australe*

## Development of cryopreservation for the recalcitrant seeded Australian plants *Syzygium australe* and *S. paniculatum*

STP 2020-063

Scientist(s): B Funnekotter, E Bunn
Student: L Hou (MSc)
Academic(s): Prof R Mancera (Curtin University)

*Syzygium paniculatum* and *Syzygium australe* are two rainforest species with recalcitrant seeds that are not storable by seed banking, with *S. paniculatum* currently threatened in its native habitat. The objective of this project is to develop a viable cryopreservation protocol for these species. Tissue cultured shoots offer an alternative explant source for cryopreservation and *ex situ* conservation of these and other threatened recalcitrant-seeded Australian species. *Syzygium* species have a strong tolerance to long incubation times in cryoprotective agents (CPAs) but exhibit a complete lack of survival following liquid nitrogen exposure, which could indicate that post-cryogenic failure is primarily due to either insufficient vitrification promotion and/or insufficient suppression of ice formation. Thermo-analytical assessments (differential scanning calorimetry)

measured the extent of ice formation in shoot tissues, permitting differentiation between cell death by actual ice damage and other stress factors such as CPA toxicity and reactive oxygen species damage.

## Ecology and conservation biology of the night parrot

STP 2017-051

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

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

A paper has been published on protocols for acoustic surveys for night parrots. A manuscript on implications for management, and guidelines for appropriate management actions, has been submitted for publication in *Biodiversity and Conservation*.

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

STP 2020-061

Scientist(s): M Byrne
Student: B Nordstrom (PhD)
Academic(s): A/Prof N Mitchell (The University of Western Australia), S Jarman (The University of Western Australia)

The western swamp tortoise (*Pseudemydura umbrina*) is endemic to south-west Australia and occupies seasonal wetlands where hydroperiods are shortening due to declining rainfall. Trial assisted colonisation translocations 300-400 kilometres south of their current habitat began in 2016 to test whether *P. umbrina* can grow in cooler climates where hydroperiods are likely to be more suitable in the future. Early results indicated suitable food availability as a key component. The aims are to 1) develop novel environmental DNA methods to understand diet in new habitats; 2) document foraging behaviour in relation to water temperatures and prey availability; 3) link metabolic processes and food intake to predict long-term growth rates and reproduction in new environments. This will provide greater certainty on whether southern wetlands can provide viable habitat for this critically endangered species in the near future.

Evaluation of juvenile tortoises released into suitable wetlands in an assisted colonisation trial showed increase in body mass over the 2021 and 2022 hydroperiods before moving into aestivation for the summer and autumn months, with a positive relationship between tortoise activity levels and carapace temperature. A highly sensitive environmental DNA (eDNA) test specific to the western swamp tortoise has been developed, which can successfully detect the tortoises at assisted colonisation sites. A molecular dietary analysis is underway to better understand the tortoise's impact on their recipient ecosystem.

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

STP 2017-027

Scientist(s): M Byrne
Student: R Dillon (PhD)
Academic(s): Prof M Waycott, Dr R Standish (The University of Western Australia)

Translocations are a key conservation recovery action for threatened plant species and determining their success is an important aspect of ongoing management. This project is investigating the success of translocation in *Banksia brownii* and *Acacia rhetinocarpa* and aims to: (1) compare the mating systems and genetic diversity of translocated populations with wild populations (2) determine how reproductive output and progeny performance of translocated populations compares to wild populations and (3) assess the efficacy of using measures of mating system parameters, genetic diversity and reproductive potential to better understand translocation success. The findings have a number of potential implications for not only assessing long term translocation success, but also improving translocation design and establishment technologies.

Analysis has been completed for genetic diversity, mating system analysis, reproductive output and progeny performance data for *Acacia rhetinocarpa* and a chapter drafted. A journal article on genetic diversity, mating systems, reproductive output and pollination analysis (for one translocated *B. brownii* population and four wild populations) has been published in *Australian Journal of Botany* (Mar 2023). An additional paper using the *Banksia brownii* genetic material collections and also trait data, co-authored with researchers from Monash University has been submitted to *Restoration Ecology*. A third paper on comparison of *B. brownii* progeny fitness traits from a translocated population with those from wild populations is in draft.

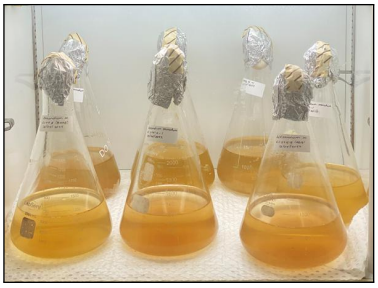
## Factors affecting the success of threatened flora translocations

STP 2017-026

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

The aim of this study is to investigate factors affecting success of plant translocations, to inform future translocations and help prevent the extinction of plant species.

The meta-analysis investigating factors influencing success of past plant translocations in Western Australia is complete, with a paper describing this work published in *Plant Ecology*. A paper on genetic diversity values and mating system parameters of translocated compared to wild source populations of *Lambertia orbifolia,* has been published in *Restoration Ecology*. Analysis of monitoring data from translocated and wild populations of *Acacia cochlocarpa* subsp. *cochlocarpa* to inform whether translocated populations have comparable demographic characteristics (plant height, volume, seed set and seed viability) to wild populations has been finalised. A glasshouse cross pollination study of *Schoenia filifolia* to evaluate whether the genetic composition of the founder populations contributes to translocation success has been completed and a paper describing this work has been published in *Australian Journal of Botany*.



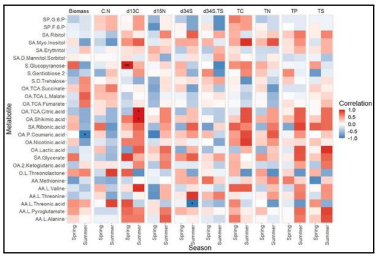
## *Alexandrium* spp. in Western Australia: characterisation, toxin mobility and control options

STP 2022-044

Scientist(s): J Cosgrove
Student: S Kwambai (PhD)
Academic(s): Dr D Laird (Murdoch University), A/Prof N Moheimani (Murdoch University), A/Prof A Lymbery (Murdoch University)

Globally, harmful algal blooms represent a major and growing threat due to their undesirable ecological, economic and health impacts. Since 2019 the Swan Canning has suffered repeated blooms of *Alexandrium, a* species that produces toxins can cause potentially fatal Paralytic Shellfish Poisoning (PSP) in humans via consumption of impacted seafood. This project investigates the toxicity and genetics of local *Alexandrium* while also investigating a potential control method. Risk of exposure to toxins when eating crabs will be investigated by measuring toxin mobility when crabs are cooked.

Investigations into control methods have found that Kaolinite clay with poly-alum chloride additive has superior control potential over bentonite clay. A manuscript reporting the results of this investigation is being finalised. A preliminary trial of crab intoxication and cook-test is currently underway. Protocols for toxin characterisation have been finalised and analysis of cultured strains is on-going.



## Tracking seagrass condition: development and application of novel molecular biomarkers

STP 2020-005

Scientist(s): J Cosgrove
Student: M Jung (PhD)
Academic(s): Dr M Fraser (The University of Western Australia), Dr B Martin (The University of Western Australia), Prof. G Kendrick (University of Western Australia)

Seagrass communities are under threat at a global scale, yet molecular physiological responses of seagrass to key stressors – such as eutrophication and sediment stress - remains largely unknown. The central aim of this project was to investigate cellular stress responses of the key seagrass species *Halophila ovalis* in the Swan Canning Estuary on a seasonal scale using novel molecular biomarker techniques such as metabolomics.

Findings were published in *Ecological Indicators* journal and reported seasonal differences in growth and stress related metabolites. The project demonstrated the value of including both traditional seagrass metrics metabolomics to help understand stress responses in the seagrass *Halophila ovalis.*

## Genetic characterisation and behavioural ecology of the western grasswren (*Amytornis textilis*)

STP 2021-043

Scientist(s): A Burbidge, S Cowen
Student: A Gibson Vega (PhD)
Academic(s): Associate Prof. A Ridley (University of Western Australia), Dr J Kennington (The University of Western Australia)

The western grasswren (*Amytornis textilis*) is restricted to Shark Bay in Western Australia and is listed as Priority Four. The Dirk Hartog Island National Park Ecological Restoration Project seeks to reintroduce a suite of locally extinct fauna to the island, including the grasswren. However, the western grasswren is probably the most poorly studied of all these species and little is known about its genetics or behaviour. The aim of this project is to

investigate the population genetics and behavioural ecology of this cryptic bird species.

Main project outputs included developing ethical guidelines for harvesting individuals and completion of the population viability analysis. There was also an update on the population genetic analysis using updated SNP data, as well as provide finer scale detail about where to harvest individuals from to capture as much genetic diversity as possible in the founder population. All analysis conducted provided guidance on aspects of the translocation of western grasswren to Dirk Hartog Island. Two manuscripts have been published.

## Dirk Hartog Island fauna reintroductions disease risk analysis

STP 2021-033

Scientist(s): S Cowen, C Sims
Student: Dr F Knox (PhD)
Academic(s): Dr R Vaughan-Higgins (Murdoch University), A/Prof K Warren (Murdoch University)

This project aims to develop disease risk analyses (DRAs) for several species in the fauna translocations to Dirk Hartog Island (DHI). By identifying key disease risks related to these translocations, mitigation measures such as screening for specific pathogens can be put in place.

A DRA for rodents (both naturally occurring and those species to be translocated) was completed and a DRA for boodies has commenced. Based on the recommendations from the rodent DRA, a screening program for pathogens in rodents on DHI is being developed and sampling of house mice and *Pseudomys* spp. is occurring for this purpose.

## Conservation genetics and population modelling to secure wild populations of the Shark Bay mouse (*Pseudomys fieldi*)

STP 2021-032

Scientist(s): S Cowen
Student: R Quah (MSc)
Academic(s): Dr D White (University of Western Australia)

In order to optimise the translocation outcomes for the proposed translocation of Shark Bay mice to Dirk Hartog Island, the population genetics of the three extant populations of the species will be investigated. This work will be used in a population viability analysis (PVA) model to inform optimal founder size and ratios, while minimising the impact on the source population(s).

Results of this work found that all three Shark Bay mouse populations have relatively low genetic diversity and differentiation between populations, with marginally more variability present in the original source on Bernier Island. The PVA suggested that the optimal ratio of founders was 80 from Northwest Island and 40-50 from Bernier Island in a female-biased (1.5:1) sex ratio, the first stage of which has now been implemented.

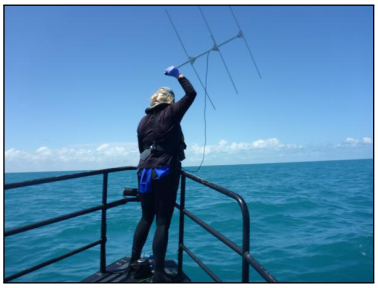
## Comparative analysis of diet in island populations of banded and rufous hare-wallabies in Shark Bay

STP 2021-031

Scientist(s): S Cowen
Student: R Stover (MSc)
Academic(s): Dr A Hopkins (Edith Cowan University), Dr R Davis (Edith Cowan University), Dr H Mills (The University of Western Australia)

Banded and rufous hare-wallabies are threatened species that have been the subject of conservation translocations to Dirk Hartog Island as part of the Dirk Hartog Island National Park Ecological Restoration Project. These species co-exist on Bernier and Dorre Islands, but little is known of their inter-specific interactions. This project aims to understand how the diet of banded and rufous hare-wallabies may influence the outcomes of the ecological restoration of Dirk Hartog Island.

All scat samples chosen for the dietary analysis in this project have had DNA extracted, amplified using two primer sets, and sent for sequencing. Sequencing results have been returned for the first primer set and bioinformatic analysis for these are in progress. Writing has commenced for diet study chapters and a review-style paper/chapter. Planning for a glasshouse trial is underway.



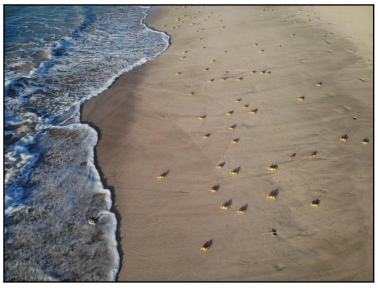
## Ecology of flatback turtles (*Natator depressus*) at a coastal foraging ground, Western Australia

STP 2020-025

Scientist(s): S Fossette-Halot
Student: J Hounslow (PhD)
Academic(s): Dr A Gleiss (Murdoch University)

This project aims to improve our understanding of flatback turtles using bio-logging tools such as daily diaries and animal-borne video cameras that collect accelerometry, orientation and swimming performance data. Data are used to analyse the turtles' fine-scale vertical and horizontal movements at a foraging ground.

Three papers were published describing flatback diving behaviour at their foraging ground and predator interaction that inform dynamic spatial management of this species in Roebuck Bay Marine Park. Tide and season have been found to strongly impact the turtles' behaviour in the bay. Detailed maps are being produced to help management. A final paper is in preparation and involves incorporating behaviour into habitat suitability modelling in a case study for sea turtles at foraging sites.



## Understanding predator-prey interactions between ghost crabs and marine turtles for better management of an endangered species

STP 2020-024

Scientist(s): S Fossette-Halot, S Whiting
Student: C Avenant (PhD)
Academic(s): A/Prof G Hyndes (Edith Cowan University)

This project examines predator-prey interactions between ghost crabs and hatchling sea turtles on the Ningaloo coast and the Pilbara to better conserve threatened turtle species and manage a native predator. It provides critical information regarding the potential impact of native ghost crabs on turtle eggs and hatchling survival. Results are helping assess the vulnerability of different nesting sites and determine if there is a need for human intervention.

Two papers have been submitted to peer-reviewed journals. The results suggest that <20% of the eggs laid at *C. caretta* rookeries on the Ningaloo coast successfully hatch and survive the beach crawl to the water mark. Nest inventories implicated native ghost crabs (*Ocypode* spp.) as the main egg predator at both locations. Additionally, hatchlings were directly and indirectly preyed on via ghost crabs by silver gulls. Predation rates found in this study were higher than those in most studies across the globe. Thus, conservation strategies to reduce predation of *C. Caretta* eggs and hatchlings in teh region seem urgently needed. Results from this project are being used to determine what the next management actions should be in regard to the high level of predation sustained by the Western Australia loggerhead turtle stock.

## Predicting the vulnerability of flatback turtle rookeries to a changing climate

STP 2019-047

Scientist(s): S Fossette-Halot
Student: M Gammon (PhD)
Academic(s): A/Prof N Mitchell (The University of Western Australia)

This project aimed to predict the vulnerability of flatback turtle rookeries on the North West Shelf to increasing sand temperatures, sea level rise and increased storm frequency. It has provided critical information for the management of marine turtles and their rookeries by assessing vulnerability and long-term conservation value of different nesting sites and determine if there is need for human intervention.

A paper has been accepted for publication in *Ecosphere*. The paper describes the vulnerability of flatback turtle rookeries to erosion and inundation and provides a decision tool for the NWSFTCP to make management decisions for this flatback stock. A presentation about these results was made at the 58$^{th}$ Australian Marine Sciences Association Conference.

## The influence of mining on the movement ecology and behaviour of the endangered northern quoll (*Dasyurus hallucatus*)

STP 2022-002

Scientist(s): L Gibson
Student: M Cowan (PhD)
Academic(s): A/Prof D Nimmo (Charles Sturt University), A/Prof S Setterfield (University of Western Australia)

The northern quoll (*Dasyurus hallucatus*) is a nocturnal mesopredator threatened by habitat loss due to mining in the Pilbara region of Western Australia, and the impacts of mining on the movement and behaviour of northern quolls are poorly known. This project seeks to fill this knowledge gap and identify the movement and behaviour of northern quolls living in mining landscapes.

Northern quolls living in the mining landscape situated their broad movement ranges in areas with high proportions of remnant rocky habitat and used all other habitats in proportion to their availability, including mining habitats. On a fine scale, quolls avoided mining habitats relative to rocky habitat in breeding season but used mining habitats at a similar rate to rocky habitat in non-breeding season. This increased use of mining habitats resulted in an increased energetic cost for quolls, potentially leading to sublethal effects such as decreased body condition. The investigation of animal abundances around mining camps using camera traps is ongoing, with all fieldwork completed and image identification and analyses underway.

## Environmental DNA as a tool to monitor fish movement in the Canning River

STP 2021-038

Scientist(s): J Hyde, S Thompson
Student: E Stevens (MSc)
Academic(s): Dr L Beesley (The University of Western Australia), Dr D Gleeson (The University of Western Australia)

This project investigated the potential of eDNA to monitor fish in the Canning River. It compared fish assembly data from traditional fyke netting, active filtration eDNA and passively collected eDNA to explore the sensitivity of eDNA survey techniques for monitoring native and invasive species in freshwater ecosystems. The influence of

biotic factors (including length) and the environment (pool volume) on eDNA detection of fish was analysed.

DNA extractions, PCR analysis and sequencing of samples collected from 10 sites between dams and weirs is complete. A paper is currently being finalised, using additional sequencing data for the reference library. The study demonstrated that eDNA can detect a wide range of fish taxa and is less labour-intensive than fyke netting. The project also highlighted significant gaps in the reference database for Western Australian freshwater species, providing guidance for expanding the reference library for freshwater macrofauna in south-western Australia.

## A genecological assessment of seed sourcing strategies for plant community restoration under environmental change

STP 2019-003

Scientist(s): S Krauss, J Stevens
Student: B Mirfakhraei (PhD)
Academic(s): Dr E Veneklaas (The University of Western Australia)

This research aimed to comprehensively test the influence of climatic and edaphic variation on the performance of genotypes from multiple provenances, to identify best-practice seed sourcing for restoration. Although many strategies for seed sourcing have been proposed, there are few empirical tests of different strategies. In this project, multiple genetic provenances of *Banksia menziesii*, a restoration priority plant species on the Swan Coastal Plain, were tested in post-mining rehabilitation field sites, as well as glasshouse growth trials where environmental parameters were modified. In addition, physical, chemical and biological properties of soils from these multiple source sites were assessed and compared to the performance of seeds sourced from these sites.

The project is complete and key findings included glasshouse studies that showed seedlings sourced from wetter regions showed higher growth and mortality when exposed to drought, whereas plants from drier seed sources had lower growth and did not show mortality when exposed to drought. Soil microbiome community and physicochemical analyses from remnant populations of *Banksia menziesii* across its range showed significant correlations between soil microbiome, soil physicochemical and climate distances. Results of a field trial identified that seed from drier provenances did not show superiority under initial field conditions. All results have been interpreted to better inform seed sourcing strategies under changing environmental conditions.

## Non-invasive collection of genetic samples from brushtail possums (*Trichosurus vulpecula*) in the arid zone

STP 2021-041

Scientist(s): C Lohr
Student: C Wang (BSc Honours)
Academic(s): Dr A Koenders (Edith Cowan University)

The status of local populations of a species must be assessed prior to further supplementary translocations. Brushtail possums were reintroduced to the Matuwa Indigenous Protected Area in 2007 under the assumption that the local population was extinct. Concerns were raised about potential bottlenecking of sub-populations of the translocated possums in 2017. This project investigated whether viable genetic material could be collected from brushtail possums in the arid zone via baited tracking tunnels; whether there is ongoing evidence of inbreeding or genetic bottlenecking in the brushtail possum population on Matuwa; and whether the phylogenetics of brushtail possums in the arid zone can be assessed through fecal or hair DNA collected through non-invasive techniques.

Unfortunately, viable DNA could not be extracted from either tracking tunnels or relatively fresh possum scats collected near trees. DNA was extracted from two out of 20 preserved possum skins held by the WA Museum, one from Cranbrook and a second from Bendering. Structure analysis of DNA taken from translocated possums suggests considerable genetic admixture between founder populations has occurred. Principal components analysis suggests that the population at Matuwa is significantly different to animals from Cranbrook.

## The effect of diet on the growth and reproduction of western swamp tortoise at Perth Zoo

STP 2018-124

Scientist(s): P Mawson
Student: G Wilkinson (MSc)
Academic(s): Prof P Horwitz (Edith Cowan University)

The captive breeding for release program at Perth Zoo for the Western Swamp Tortoise (*Pseudemydura umbrina*) makes an essential contribution to the species' long-term conservation prospects. In doing so, the program has generated a considerable database on the biology of the captive population. This study investigated retrospective data collected across a total of 9 breeding seasons (years) to determine the factors that influence the species' growth and reproduction in captivity.

Diet was the main factor focussed on since nutrition provision is a key husbandry area that is made difficult trying to replicate a species' highly specialised wild diet in captivity to a large-scale breeding program. Minor nutritional differences were found between the predominantly red-meat and white-meat only captive diets; the white diet had slightly higher protein and protein to energy ratio, while the red diet had a higher fat content. Captive diets fed to offspring did not show consistent differences for all juvenile growth or aestivation periods. Where differences did occur, the red diet yielded a significantly higher specific growth rate than the white diet. Captive diet fed to breeding females was a more prevalent factor across the reproductive variables with a general, but again not consistent, trend of (where it occurred) the white diet having significantly higher reproductive performance than the red diet. Given the species resilience to reproduce and grow in captivity regardless of minimal nutritional differences, the white captive diet is recommended as more appropriate to the breeding program overall. Of all the factors examined, the variability between breeding seasons was the most consistently significant difference for growth and reproductive variables. These findings considered together highlight the multi-factorial relationship between nutrition, growth and reproduction and the areas still needing further research, like environmental factors in captive breeding settings themselves.

## Predicting effects of climate change and thinning on growth, health and water yield of jarrah and karri stands using individual-based modelling

STP 2018-081

Scientist(s): R Mazanec
Student: S Bhandari (PhD)
Academic(s): Dr E Veneklaas (The University of Western Australia), Dr M Renton (The University of Western Australia)

The jarrah (*Eucalyptus marginata*) and karri (*Eucalyptus diversicolor*) forests of south-west Western Australia provide a variety of values including timber, wildlife habitat and water. However, as climate changes, issues of forest productivity, tree health and mortality, and water yield need to be addressed. Individual-based modelling (IBM) is an ecological modelling approach that represents individuals within populations or communities, and the interactions between them, with a relatively high level of detail and complexity. This study aims to develop an IBM of tree growth in water limited environments, to parameterise the model for jarrah and karri and to predict the impact of tree thinning on timber production, tree health and mortality and water yield using time series data collected from 1965 and 1992, respectively.

This research has shown that thinning has a positive impact on the growth of both species, with stand growth optimised at intermediate densities (10-20 $m^2$ $ha^{-1}$) over multi-decadal time periods, consistent with findings from previous studies. Thinning also influences allometry of stem diameter with height, ratio of height and diameter, crown width and bark thickness. Two papers were published: the first on the effect of thinning on growth and allometry of karri was published in *Southern Forests* and the second investigating the effects of above and below ground competition in jarrah and karri forests was published in *Forest Ecology and Management*.

## Ecophysiology of seed dormancy of *Hibbertia*

STP 2022-009

Scientist(s): D Merritt
Student: S Henningsen (PhD)
Academic(s): T Erickson (The University of Western Australia)

Seed collecting trips were undertaken during Nov-Dec 2022, sourcing 23 collections of 10 species. Experiments on freshly collected seeds to quantify the depth of dormancy and sensitivity to smoke amongst the seed populations have been completed, with all species proving to be deeply dormant, as expected.

Laboratory experiments examining seed dormancy break requirements are in progress, focussed on the impacts of light conditions during warm or cold stratification, or wet/dry cycling. New seed collections will be sourced over summer 2023 and multi-year seed burial experiments will be implemented to study under field conditions seed dormancy break, the onset of embryo growth and germination timing, and persistence, both within and between species.

## Assessing ecological resilience of post-mining restoration: testing fire recovery across a restoration chronosequence

STP 2019-060

Scientist(s): B Miller
Student: E Cowan (PhD)
Academic(s): Dr J Fontaine (Murdoch University), Dr R Standish (Murdoch University)

Ecosystem resilience is the ability of an ecosystem to return to its former state following a disturbance, and is a key factor in evaluating the success of ecological restoration efforts. Resilience is difficult to measure and is unknown for many restored communities. This project investigates the resilience of banksia woodlands restored after sand mining to fire, specifically seeking to determine an age when restoration is resilient to fire. Investigations will assess resprouting capacity and soil seedbank dynamics across a chronosequence of ages between three and 27 years since restoration.

Experimental fire has been introduced to sites across the chronosquence and post-fire regeneration monitored for 1.5 years. Regeneration from soil seedbanks and resprouting was observed, with factors including size, restoration age and soil compaction influencing resprouting success. There is evidence of sites returning to a similar pre-fire state following fire, with some differences in perennial vegetation composition remaining between restored and intact sites.

## Shifting soil fungal communities in response to fire and weed management in urban banksia woodlands

STP 2019-052

Scientist(s): B Miller, K Ruthrof
Student: A Brace (PhD)
Academic(s): Dr A Hopkins (Edith Cowan University), Dr J Fontaine (Murdoch University)

Issues arising from habitat fragmentation are exacerbated by a warming and drying climate, land use changes and invasive species. To maintain biodiversity, various management methods are employed, such as prescribing burning or herbicide application. Many of these strategies are macro-organism focused, with less attention paid to microorganisms. Soil fungi play instrumental roles in ecosystem functioning, yet in many ecosystems little is known about how soil fungi respond to prescribed burning and weed control. The Swan Coastal Plain's Banksia

woodland is one such ecosystem where there is a gap in knowledge. This project will help fill that knowledge gap and better inform management decisions.

All planned analyses have been completed and journal manuscripts drafted, to answer four key questions regarding the responses of soil fungal communities to 1) time since fire over a 50-year chronosequence, 2) time since fire within the first year, 3) fire and herbicide under field conditions, and 4) a range of herbicides under glasshouse conditions. A breadth of fungal sequences (~20,000) has been identified, with various taxonomic and functional information being assigned. Results suggest that the soil fungal community is very dynamic in the early months of recovery in the post fire environment, but over time it gradually increases in diversity but decreases in relative abundance before plateauing ~30 years post-fire. Herbicide application has complex effects on the soil fungal community within field applications suppressing all observed metrics, but *ex-situ* application of a herbicide increased abundance and richness, especially of pathogenic species.

## Ecologically tolerable fire regimes for key banksia woodland plant species

STP 2018-089

Scientist(s): B Miller, D Merritt
Student: R Miller (PhD)
Academic(s): Dr J Fontaine (Murdoch University), Prof N Enright (Murdoch University)

Fire is a dominant disturbance that shapes species and ecosystems. Many plant species have developed strategies and adaptations to cope with certain fire regimes. If fire occurs too frequently, too intensely, or otherwise outside of the limits of a species' tolerance, then populations are likely to decline or disappear. This project aims to determine the impact of varying fire regimes on the demographics of key banksia woodland plant species.

Data collection and analysis have been completed. Demographic surveys have identified changes in population size structures, flowering and canopy seed bank accumulation for six woody plant species. Some species have evidence of inter-fire recruitment. Juvenile periods ranged from 1.3-4.1 years and varied by fire response, seed bank storage mode and growth form. Canopy seed banks were not observed to accumulate over time, consistent with observations of weak serotiny in banksia woodlands. A field experiment showed how timing of seed planting throughout the year (emulating the timing of fire) influences seedling recruitment, where recruitment is best when seeds are cued for germination immediately prior to winter rainfall. One review paper (on fire season effect mechanisms) and one experimental paper (on fire seasonal germination and emergence patterns) have been published. Papers on population structure and reproductive patterns are in late draft.

## Microplastic distribution, sources, ingestion and health impacts in urban estuarine environments

STP 2022-006

Scientist(s): P Novak
Student: T Crutchett (PhD)
Academic(s): R Hovey (UWA)

This project extends on the recently published a departmental report on plastic contamination in the Swan Canning Estuary by determining the presence of microplastics (plastics <1 mm) in surface water and beaches of the estuary. The project will develop a method to identify the polymers of these tiny plastics and investigate the presence of microplastics in the digestive systems of fish and determine the potential harm caused by these materials.

An extensive review of the literature has been undertaken and a pilot trail completed to test and refine water and beach sampling methods. Eight quarterly sampling events at 38 beach sites and four estuary regions

have been completed. Analytical methods for plastic fragment identification have been developed and sample processing has commenced. The literature review is being developed into a journal article.

## Plastic pollution in urban drains

STP 2022-005

Scientist(s): P Novak
Student: M Williams (PhD)
Academic(s): A/prof J McIlwain (Curtin University)

The recent report on plastic contamination in the Swan Canning Estuary highlighted some major differences in the plastic accumulation on beaches within different regions of the estuary. This work aims to determine if there are differences in the amount of plastic washing down the major drainage lines. In addition, this work will determine the types of plastic commonly washing down the drains into the estuary, providing vital knowledge for the Plastic Free Riverpark Program to identify priority catchments for remediation work.

Sampling has now been completed at six catchment sites, three in the Canning catchment and three in the Swan catchment. Sampling was undertaken over three time periods, winter storm event, winter base flow and first major flush event. Samples from the major flow event are still being processed. Data has been collated for the winter base flow and winter flow event samples. A report is in preparation.

## Canning River water quality and macrophyte investigation

STP 2022-004

Scientist(s): P Novak
Student: A Gillies (PhD)
Academic(s): A/Prof N Callow (University of Western Australia)

Submerged macrophytes play a fundamental role in the functioning of freshwater lakes and rivers providing food, refugia, shade and influencing physico-chemical conditions. A submerged macrophyte community has been an important part of the Canning River Kent Street Weir Pool (KSW) for decades. Recent observations suggest it has disappeared from the weir pool. This project aims to determine the changes in water quality in the weir pool over the last 20 years, determine the historical extent of submerged macrophytes in the weir and investigate reasons for their changes in abundance.

This research has confirmed that there was no submerged macrophyte community in the KSW and determined that it had been consistently absent since 2017. Changes in light levels, influenced by management of the upgraded weir, were suggested as the likely cause of macrophyte loss. A journal article is in development.

## Landscape genetics of red-tailed phascogales in south-west WA

STP 2022-037

Scientist(s): K Ottewell
Student: R de Visser (BSc Honours)
Academic(s): Dr R Catullo (University of Western Australia), Dr M Hall (Bush Heritage Australia)

The red-tailed phascogale, *Phascogale calura*, is listed as conservation-dependent. Due to their highly fragmented and restricted habitat in south-west Western Australia, understanding their genetic structure and diversity can inform conservation action. This study aims to 1) assess genetic structure across wild reserve

populations, 2) assess genetic diversity within reserves, 3) determine the genetic outcome of a previous mixed wild-to-wild translocation to Kojonup reserve, and 4) estimate effective wild global population size.

Genomic analysis was completed for 208 samples from 9 reserves. An isolation by distance model best explained the genetic structure, with similar levels of genetic diversity reserves, and no populations showed signs of inbreeding or strong genetic drift. Although Kojonup has retained the diversity of the wider species, the source populations were unevenly represented. Although populations appear to retain connectivity currently, global effective population size was low (Ne 48-117) suggesting the species is vulnerable to future genetic diversity loss.

## Understanding patterns of phenotypic and genetic divergence in island mammals to improve conservation outcomes

STP 2021-030

Scientist(s): K Ottewell
Student: K Rick (PhD)
Academic(s): A/Prof N Mitchell (University of Western Australia)

This project will focus on quantifying phenotypic and genetic divergence amongst island and mainland populations of several threatened mammals including the burrowing bettong (*Bettongia lesueur*), golden bandicoot (*Isoodon auratus*) and the dibbler (*Parantechinus apicalis*) to determine whether genetic and morphological differentiation between remnant populations reflects divergent adaptation or are artefacts of genetic drift, and the consequences for mixing populations of each species.

A population genomic assessment for island and mainland golden bandicoots has been completed and a manuscript submitted. Morphological measurements of museum specimens of dibbler and the burrowing bettong have been completed and a morphological assessment is underway to investigate broad patterns of adaptation.

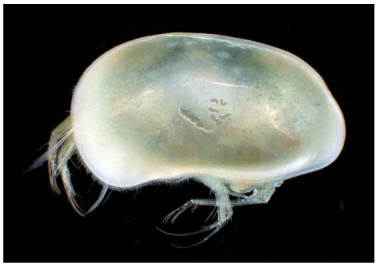
## Taxonomy and evolutionary history of *Parartemia* brine shrimp from Australian salt lakes

STP 2020-013

Scientist(s): A Pinder
Student: A Islam (PhD)
Academic(s): Dr J Chaplin (Murdoch University)

Australia has many salt lakes that support a diverse range of invertebrates. Crustaceans are particularly dominant and many species, genera, and even some families are endemic to these environments. The brine shrimp genus *Parartemia* is a good example, being one of the most diverse, common, and salt-tolerant groups of invertebrates that only occurs in Australian salt lakes. This research focuses on brine shrimp in Australia, with three main aims: 1) use mitochondrial and nuclear markers to evaluate the current morpho-taxonomy of *Parartemia*, 2) use molecular data to understand the evolutionary history and phylogeography of *Parartemia*, and 3) examine the distribution and phylogeography of the introduced *Artemia* in Australia.

A manuscript reviewing knowledge of *Parartemia* is nearing completion. Extensive sampling of COI, 16S and 28S sequences have provided evidence of some new species and conspecific morphotypes within *Parartemia* and a phylogenetics manuscript is in preparation. Writing is in progress for a phylogeography manuscript. Genetic markers (both mitochondrial COI and nuclear ITS-1) are being used to trace the origins and spread of *Artemia* lineages in Australia. All fieldwork, lab work, and data analyses have been completed, and the writing of this thesis chapter is currently underway.



## Taxonomy and evolutionary history of *Australocypris* giant ostracods from Australian salt lakes

STP 2020-012

Scientist(s): A Pinder
Student: M Rahman (PhD)
Academic(s): Dr J Chaplin (Murdoch University)

Salt lakes are a distinctive feature of Western Australian inland areas. Several invertebrate groups appear to be far more diverse in Western Australia than anywhere else in Australia and even globally, probably reflecting the long history of aridification and the now disjunct occurrence of this type of wetland in the State. Salt lakes and their biota are threatened by altered hydrological processes and changes in water quality associated with land clearing (especially in the Wheatbelt) and increasingly, by mining on or near the lake bed. The first goal of the project is to use mitochondrial DNA data and, if necessary, nuclear DNA data, to assess the validity of the morpho-taxonomy of genus *Australocypris* and to examine mytilocyprdine systematics generally. The second goal is to use molecular data to test alternative hypotheses about species radiations in *Australocypris*. The final goal is to develop a protocol for hatching and raising adult ostracods from resting eggs in mud samples collected from dry lakes, as a substitute for collecting active ostracods.

A review article on giant ostracods has been published in *Marine and Freshwater Research*. Extensive genetic analyses have been conducted and a manuscript on the systematics of mytilocypridine ostracods is in preparation. Investigations into the phylogeography and evolutionary history of *Australocypris* ostracods has been completed and a draft manuscript completed. An experimental analysis of hatching conditions for mytilocypridine eggs has been carried out and analyses completed. A manuscript is nearing completion.

## Taxonomy, ecology and evolutionary history of the salt lake gastropod *Coxiella*

STP 2020-010

Scientist(s): A Pinder
Student: A Lawrie (PhD)
Academic(s): Dr J Chaplin (Murdoch University)

Salt lakes are an iconic feature of Western Australian semi-arid and arid landscapes. Western Australia has a particularly diverse halophilic fauna. Salt lakes and their biota are threatened by altered hydrological processes and changes in water quality associated with land clearing and, increasingly, by mining. One of the most intriguing invertebrate groups is the snail genus *Coxiella*, which tolerates periodic drying and high salinities and is the only mollusc occurring in temporarily filled salt lakes. This project focusses on the phylogenetics, phylogeography and physiology of this genus.

A taxonomic assessment of *Coxiella* has identified 14 species, with 6 considered to be new. This study also included *Tomichia* from South Africa and *Idiopyrgus* from South America and confirmed that these plus *Coxiella* form a family with Gondwanan origins. The phylogeographic study suggested diversification of *Coxiella* began during the early to mid-Miocene, followed by speciation during the mid to late Miocene and diversification within species during the Pliocene/Pleistocene. Analyses indicated that phylogeographic structure and genetic diversity vary according to biogeography and climatic history. Species exhibited two broad patterns consistent with their distributions in relation to rainfall. Results of salinity tolerance experiments suggested that all *Coxiella* species can persist across a wide range of salinities (at least 5 – 90 mS/cm) but upper limits vary between species. *Coxiella* n. sp 2, in particular, was able to tolerate ~ 135 mS/cm, suggesting that this species may be one of the most salt tolerant gastropods globally.

## Influence of fire history and seed distribution on the movements of granivorous finches in the East Kimberley

STP 2019-057

Scientist(s): I Radford
Student: S Collett (PhD)
Academic(s): Dr H Campbell (Charles Darwin University)

According to ecological theory, sympatric species cannot occupy the same niche space. Therefore, the coexistence of sympatric species is thought to be facilitated by the partitioning of resources, differing patterns of habitat utilisation, or both. However, in the tropical savannas of northern Australia 3 sympatric grass finches co-exist. It is thought that the threatened Gouldian finch has a specialised diet of grass seeds and also morphological adaptations for greater dispersal. In contrast, the more common Long-tailed and Masked Finches have a generalist diet, including a greater range of herbaceous seeds and invertebrates, and are also more sedentary in their habitat use and movements. Fire regimes leading to increased movements to locate specialist food resources may increase risks to Gouldian finches, including starvation and/or lost body condition. This study uses stable isotope analysis and novel radio telemetry methods to test hypotheses on diet specialisation, and foraging behaviour in the Kimberley savanna as resource bottlenecks increase as grass seeds become more scarce into the late dry season.

Analyses showed that Gouldian finches visited waterholes less often per day than other finches, leading to over-estimations of some species. Consistent with predictions based on wing length/diet, Gouldian finches dispersed more, and spent less time at foraging sites as seed density declined through the dry season. Masked and long-tailed finches changed diet instead of increasing searches for grass seeds. Gouldian finches preferentially foraged where prescribed burning had occurred, and grass seeds were denser. Late dry season and wet season burnt, and long unburnt habitats were not selected by finches. Two papers were published, another has been accepted and two draft papers are in development.

## Extending aerial surveys beyond target marine mammal species: an application of strip transect methodology to humpback whale abundance estimation in Exmouth Gulf, WA

STP 2022-031

Scientist(s): H Raudino, K Waples
Student: J Tucker (BSc Honours)
Academic(s): Dr C Salgado Kent (Edith Cowan University)

Aerial survey is a standard technique used in wildlife management to estimate population abundance and detect trends. It is particularly useful for species with large ranges and broad distribution patterns, such as marine mammals, as the technique allows relatively large areas to be covered over short periods of time. While aerial surveys are typically designed for specific target species, additional species are often recorded as surveys are generally infrequent due to expense and logistical constraints. Analyses to estimate abundance of non-target species recorded during surveys can have limitations as information recorded for these species may be constrained or incomplete. In this study, analysis of aerial survey data collected in Exmouth Gulf, Western Australia, will be extended beyond the target species (dolphins) and applied to humpback whale (*Megaptera novaeangliae*) abundance estimation. While the survey was designed for distance sampling abundance estimation of dolphins, a strip transect approach was taken for humpback whales, and a maximum strip width was not defined. This study will evaluate various strip width estimates derived from the detection functions of comparable cues and a field based trial. An absolute abundance estimate for humpback whales will be calculated using strip-transect based methods, with corrections for availability and perception bias. The methods used here will be evaluated through comparison of these estimates with those derived from photographs taken during the survey, which have a known strip width. The relative density distribution of the species within the area will also be mapped and evaluated. The results of this study will update current knowledge on the abundance and distribution of key marine mammals with a focus on humpback whales in Exmouth Gulf, to inform ongoing monitoring and management of this ‘conservation dependant’ population.

The aerial imagery has been compiled and reviewed to address the biases inherent in aerial survey data. This has included conducting an additional single day of aerial survey to detertmine detection function and strip width for the analysis. The results are being written up.

## Implications of ecological thinning on jarrah forest fuels and potential fire behaviour

STP 2023-012

Scientist(s): K Ruthrof
Student: S Brennan (MSc)
Academic(s): Dr J Fontaine (Murdoch University)

A chronic downward trend in rainfall in southwestern Australia has resulted in significant declines in groundwater levels and streamflow in the forest estate. In addition, historical silvicultural techniques have resulted in many areas of the *Eucalyptus marginata* (jarrah) forest developing altered stand characteristics of high stem densities with high water usage when compared to old-growth forest stands. Ecological thinning is a forest management technique to alleviate the water stress in stands with high stem densities. The method of thinning is an important consideration as it affects biomass distribution and, as a result, fuel arrangement in the forest. As jarrah forest ecosystems include fire disturbance regimes, it is necessary to consider how Jarrah forests fuel complexes respond to thinning. This project will help fill the knowledge gap that exists in the context of a jarrah forest fuel complex responding to ecological thinning management techniques.

Quantification of the surface fuel and canopy strata has been undertaken using both remote sensing and manual field collection methods. This will contribute to models that identify potential fuel and fire hazard and behavior.

## The influence of drought on plant morphology, physiology and establishment in the post iron ore mining environments of semi-arid Western Australia

STP 2018-147

Scientist(s): J Stevens
Student: S Sullivan (PhD)
Academic(s): A/Prof P Poot (The University of Western Australia), Dr E Veneklaas (The University of Western Australia)

Mining companies have a legal responsibility to return native biota to post-mining environments; although ecological restoration is challenging, especially in water limited environments. The chemical and physical properties of substrates do not always explain high seedling mortality therefore other factors such as drought should be explored. This research project aims to improve restoration outcomes by obtaining a greater understanding of the influence of soil water availability and phenotypic plasticity on juvenile plant morphology, physiology and survival in the post iron ore mining environments of semi-arid Western Australia.

All experimental work has been completed including research to (1) understand germination thresholds of semi-arid restoration priority species, (2) investigate how preconditioning seedlings to water stress influences tolerance to subsequent drought in restoration substrates, and (3) understand how propagule type, substrate and water availability influence establishment in restoration environments. Analysis and writing is underway.

## Near-surface remote sensing of plant condition in mine site restoration environments

STP 2018-146

Scientist(s): J Stevens
Student: J Ruscalleda Alvarez (PhD)
Academic(s): Dr J Yong (The University of Western Australia), Dr E Veneklaas (The University of Western Australia)

Plant physiological condition is a key indicator in the early stages of restoration progress assessment. Current methods to determine condition are difficult to undertake over large areas and are time-consuming. This research project aims to determine if near-surface remote sensing measurements (particularly hyperspectral sensing and thermography) can reliably quantify plant drought stress condition in a biodiverse plant community. Quantitative criteria will be proposed to evaluate restoration success by defining a fast, accurate, and easy to perform methodology, potentially establishing the foundation for scaling up remote imaging platforms that allow monitoring of larger areas in shorter timeframes.

Experiments were completed in glasshouse and filed conditions to explore hyperspectral reflectance (measured with a field spectrometer) as a predictor of plant water status, plant water content, pigment content and maximum potential quantum efficiency of Photosystem II, as well as leaf temperature (measured through thermal imagery) to predict stomatal conductance. This approach has now been applied to Banksia woodland restoration sites where five functionally distinct plant species were monitored over 15 months.

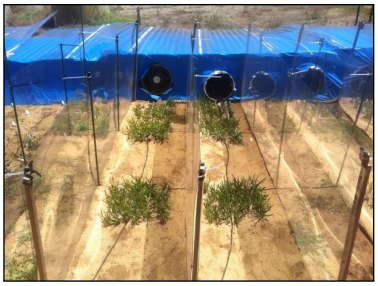
## Soil-microbial-plant signals and effects on plant eco-physiological performance for mine site restoration

STP 2018-145

Scientist(s): J Stevens
Student: W Wong (PhD)
Academic(s): A/Prof R Trengove (Murdoch University), Dr J Yong (The University of Western Australia), Dr E Veneklaas (The University of Western Australia)

The importance of soil biological properties such as microbial composition and the benefits conferred to soils and plants are often undervalued in mine site restoration. Microorganisms have been widely reported to be beneficial for agricultural crops for example through growth stimulation, increased nutrient uptake and plant tolerance against abiotic stress such as drought induced by microbial phytohormone and enzyme signals. Some of these beneficial microorganisms are also present in natural soil systems, however, their role in facilitating seedling establishment is yet to be identified. This project aims to investigate if microorganisms known to benefit agricultural species can be applied to Western Australian natural systems via inoculations. The project also aims to elucidate the mechanisms involved in the positive effects of microorganisms on plants and explore how these findings can be integrated to improve mine site restoration strategies.

The results of the project demonstrated rather limited beneficial effects of the selected microbial inoculants on the tested native plant species and highlights that further research is required before advocating the use of commercial microbial inoculant in post-mining ecological restoration. The work also provided an approach to evaluate the use of commercial microbial inoculants through method development and experimental approaches that will be useful for future research.



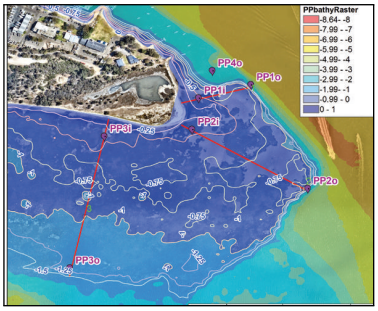
## Implications for wind management in restoration ecology, linking ecosystem aerodynamics to physiological drivers in arid and semi-arid systems

STP 2018-143

Scientist(s): J Stevens
Student: E Arora (PhD)
Academic(s): Dr A Guzzomi (The University of Western Australia), Dr S Tomlinson (Curtin University), Prof K Dixon (Curtin University)

Plant mortality in restoration programs leads to reduced outcomes for biodiversity and is costly for practitioners. Understanding the drivers of mortality, in particular factors influencing soil water availability, is critical. Wind dynamics play a significant role in drying soils and creating atmospheric deficits whereby plants lose water. In altered systems such as restoration environments, the wind dynamics may be different compared to reference communities, and may impact seedling establishment. This project aims to capture reference wind dynamics of many Western Australian ecosystems including the banksia woodland ecosystem, and compare restoration sites to the reference state. Understanding the critical thresholds for wind dynamics and the impacts on plant physiological performance will be assessed for *Banksia* species.

This study investigated canopy flow in native Australian vegetation and post-mine restoration systems. Implications for altered wind dynamics were used to understand plant functioning *in altered environments*, providing a significant insight into the role of wind as an abiotic factor in arid and semi-arid ecosystems.




## Investigating wind and wave impacts on the Swan Estuary Marine Reserve foreshore – Nedlands

STP 2023-023

Scientist(s): S Adiyanti
Student: S Lim (MSc)
Academic(s): Dr C Pattiaratchi (The University of Western Australia)

This project is investigating how the wave height, energy and erosive power at the eastern shoreline of Pelican Point is being influenced by bathymetry, storm surges, wind waves and boat wakes.

Eight pressure loggers deployed in nearshore and offshore areas between December 2022 and June 2023 have been retrieved and downloaded. Available datasets have been analysed to identify durations of significant storm surges and boat wakes, as well as durations for wave energy attenuation investigation. Matlab routine for calculating wave properties including wave energy has been created. Next steps include finalizing the wave attenuation dataset, applying appropriate time periods for analysis of durations of storms surges and boat wakes, and calculation of wave energy using wave by wave analysis.

## Understanding drivers of fish communities - Eagle Rays

STP 2023-022

Scientist(s): K Trayler
Student: E Taljaard (PhD)
Academic(s): J Tweedley (Murdoch University)

This project is using historic fish community datasets and new survey data to understand spatial and temporal patterns in the abundance of the Southern Eagle Ray (*Myliobatis tenuicaudatus*) and factors that influence these. Quantitative assessments of the biology and diet will also be determined.

Monthly sampling has occurred at six sites in the Lower Swan Canning since November 2022 and will continue through to October 2023. Physical measurements and biological data are being compiled to build age and growth relationships. Dietary assessments are underway. A background report on fish communities has been prepared to improve understanding of drivers of patterns observed in the Canning River.

## Quantifying the loss of antipredator traits in havened mammal populations and their relationship with population density and resource competition.

STP 2021-009

Scientist(s): A Wayne
Student: N Harrison (PhD)
Academic(s): A/Prof N Mitchell (The University of Western Australia), A/Prof B Pillips (University of Melbourne), A/Prof J Hemmi (University of Western Australia), Dr L Valentine (The University of Western Australia)

The aim of this project is to develop robust behavioural assays for quantifying anti-predator responses in woylies, and then use these methods to assess the potential extent of the loss of anti-predator responses, populations at risk, possible drivers, and consequences for survival and reproduction. This information will assist in informing future management and translocation practices for woylies, and potentially other critical weight range species.

Anti-predator behaviours have been compared in two populations of woylies at Dryandra and Perup. An experimental release of woylies has been conducted to investigate survival consequences of weakened anti-predator responses, adaptability of behaviours over time, and implications for conservation translocations and management.

## Survey methods and population estimates of the chuditch across its range

STP 2020-048

Scientist(s): A Wayne
Student: M Taylor (PhD)
Academic(s): Dr M Calver (Murdoch University), Dr K Bryant (Murdoch University), Dr N Armstrong (Murdoch University)

Robust population estimates are fundamental to species conservation and management. This project aims to use lured remote sensor cameras and spatially-explicit capture-recapture (SECR) modelling to improve the accuracy of density estimates for chuditch populations.

Spatial distribution of cameras was investigated for chuditch. Results suggested the use of paired cameras set horizontally at 30 cm off the ground with a grid of spacing of 1 km between sites. Comparing two spatial layouts, a grid and a road array, showed that while both layouts produced similar density estimates, but the grid was more reliable. To test the broadscale suitability of a 1 km grid, cameras were deployed in three additional locations: Dryandra National Park, Batalling State Forest and Moopinup Forest Block, and in Julimar to detect changes in chuditch detections over time. Via simulation, the reliability of the density estimates from these deployments are being used to determine adjustments to location-specific surveys to improve reliability.

## Modelling species interactions and other environmental factors in the Upper Warren

STP 2019-051

Scientist(s): A Wayne
Student: W Geary (PhD)
Academic(s): A/Prof E Ritchie (Deakin University), A/Prof D Nimmo (Charles Sturt University), Dr T Doherty (Deakin University), Dr A Tulloch (University of Sydney)

This project aimed to identify the major correlates of population changes in four critical weight range mammals (woylie, chuditch, koomal, quenda) in the Upper Warren region of Western Australia, including fire history, logging history, climate and weather variation and predator management.

First, this project modelled the associations between red fox and feral cat occurrence and fox baiting intensity, prey abundance and rainfall. Second, this project used structural equation modelling to identify primary productivity and habitat extent as key drivers of historical population change for woylie, chuditch, koomal and quenda populations, and rainfall declines and severe fire as potential drivers of future population declines. Lastly, the project used multi-species abundance modelling and optimisation analyses to demonstrate how fire and red fox management strategies might be optimised to maximise the abundance of species of conservation concern in the Upper Warren. The outcomes of this project demonstrate that managers need to consider the complexity of ecosystems and their local context when designing conservation interventions, and this must be done in an adaptive framework so that management can be continuously improved.

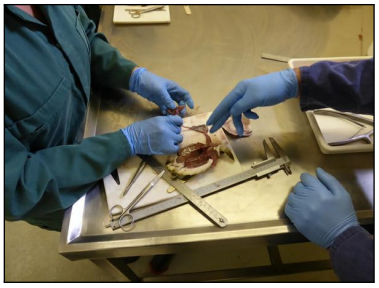
## The population and spatial ecology of the numbat in the Upper Warren

STP 2019-050

Scientist(s): A Wayne
Student: S Thorn (PhD)
Academic(s): A/Prof N Mitchell (The University of Western Australia), Dr R Firman (The University of Western Australia)

The aim of this project is to increase knowledge about the baseline population and spatial ecology of the numbat population in the Upper Warren region. This information will assist in informing future management practices for this population.

SECR design modelling, based on parameters from a field study, suggests a survey design based on static grids of 6x6 or 7x7 cameras, using Swift 3C wide angle cameras and deployed for between 60-80 days can be used to monitor numbat population trends. Numbats showed selectivity on a macro- and microhabitat scale relating to soil type, distance to a water source, distance from roads, time since timber harvesting, prescribed burning, hollow logs; based on GPS tracking technology. Median female home range size was 29.5 ha in spring and 32.7 ha in autumn (n=13 females). The home range of the two males that were tracked was 80.2 ha and 278.7 ha. A population viability analysis for the Upper Warren indicates the population is most sensitive to mortality rates of females and juveniles. Simulated scenarios suggest increased mortality rates and reduction of carrying capacity due to increased firewood collection, reduced predator control and increased effect of prescribed burning could result in a large drop in population size.



## The health status of marine turtles in northern and western Australia

STP 2016-022

Scientist(s): S Whiting
Student: E Young (PhD)
Academic(s): Dr R Vaughan-Higgins (Murdoch University), A/Prof K Warren (Murdoch University), Dr L Yeap (Murdoch University), Dr N Stephens (Murdoch University)

This project aims to assess the health and disease status of sea turtles in Western Australia, with a focus on flatback turtles. For stranded dead and injured turtles, pathology is used to diagnose the causes of death and injury, with parasite infections and fibropapilloma virus being specifically investigated. For healthy turtles the project has established a blood chemistry reference baseline which can be used nationally by turtle care facilities.

The outcomes of this project included the first health assessment of sea turtles in Western Australia, including blood chemistry and reference baselines for nesting and in-water flatback turtles. Processes for pathology and pathology descriptions for flatback turtles were developed and personnel across the state were trained. Knowledge transfer to stakeholders included support for the banning of mass balloon releases in WA. A novel disease related to a multiple species mortality event in Broome (fish kill) was identified, as were a new parasite and haemoparasites in flatback turtles. A paper has been published in the journal *Diseases of Aquatic Organisms*, three draft manuscripts are in preparation.

## Chasing Flamingos - Tracking synthetic eDNA in a river network using passive sampling methods

STP 2022-003

Scientist(s): J Hyde, G McGrath
Student: S Thompson (MSc)
Academic(s): Dr A Hopkins (Edith Cowan University), Dr A Koenders (Edith Cowan University)

Environmental DNA (eDNA) is increasingly used to survey freshwater biodiversity, but complexities of flowing waters can limit interpretation of results in riverine environments. Inferences on species distribution are based on the unidirectional flow with assumptions of how far upstream the source of the DNA might occur. This project aims to measure the movement of a synthetic DNA tracer injected into a river, and the rate of loss with distance from the source. Modelling of the experiment will be conducted to inform how eDNA sampling can be used to inform spatial distributions of biodiversity along river reaches. Outcomes from this research will assist in applying novel eDNA methods to monitor the biodiversity of flowing, freshwater ecosystems.

An experiment has been planned for Southern River and initial measurements of stream morphology and flows have been undertaken to develop a local flow rating curve. The synthetic DNA tracer and primers have been designed, based on American flamingo (*Phoenicopterus ruber*), and specificity testing is underway to ensure the final tracer will be unique to the experiment environment.

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# Summary of Research Projects

## Biodiversity Information Office

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| All Regions | All IBRA Regions | All Regions | BIO data collation program | 2 |

## Animal Science

| DBCA Region | IBRA/IMCRA | NRM Region | Project Title | Page |
|---|---|---|---|---|
| Pilbara, Goldfields | Pilbara, Gascoyne, Murchison | Rangelands | Barrow Island threatened and priority fauna species translocation program | 20 |
| Pilbara | Pilbara | Rangelands | Building resilience to change for mammals in a multi-use landscape: identifying refugia and landscape connectivity for small mammals in the Pilbara | 7 |
| Pilbara | Pilbara | Rangelands | Conservation and management of the bilby in the Pilbara | 18 |
| South Coast, Warren | Jarrah Forest, Esperance Plains, Warren | South West, South Coast | Conservation of south coast threatened birds | 22 |

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|---|---|---|---|---|
| Kimberley, Pilbara, Midwest, Goldfields | Tanami, Great Sandy Desert, Pilbara, Carnarvon, Little Sandy Desert, Gibson Desert, Gascoyne, Murchison, Great Victoria Desert | Rangelands | Conservation of the night parrot | 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 | 25 |
| Midwest | Yalgoo, Shark Bay | Rangelands | Dirk Hartog Island National Park Ecological Restoration Project – fauna reconstruction | 15 |
| Wheatbelt, South Coast | Avon Wheatbelt, Coolgardie, Mallee, Esperance Plains | South Coast | Distribution and conservation status of the heath mouse (*Pseudomys shortridgei*) in Western Australia | 5 |
| Pilbara | Pilbara | Rangelands | Ecology and management of the northern quoll in the Pilbara | 23 |
| Pilbara, Midwest | Pilbara, Gascoyne | Rangelands | Ecology, threats and monitoring of the Pilbara Olive Python (*Liasis olivacea barroni*) | 10 |
| Warren | Jarrah Forest | South West | Felixer grooming trap trial: Feral cat control for threatened fauna conservation in the southern forests. | 8 |
| Kimberley, Pilbara | Northern Kimberley, Central Kimberley, Dampierland, Pilbara | Rangelands | Genetic assessment for conservation of rare and threatened fauna | 19 |
| Pilbara | Pilbara | Rangelands | Genetics of Pilbara threatened bats | 6 |
| Kimberley | Victoria Bonaparte, Northern Kimberley, Ord Victoria Plain, Central Kimberley | Rangelands | Impact of cane toads on biodiversity in the Kimberley | 24 |
| All Regions | Gascoyne | All Regions | Improving the use of remote cameras as a survey and monitoring tool | 17 |

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|---|---|---|---|---|
| Midwest, Wheatbelt, Swan, South Coast, South West | Geraldton Sandplains, Avon Wheatbelt, Coolgardie, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren | Wheatbelt, Avon, Swan, South West, South Coast | Investigation into the decline of Chuditch (*Dasyurus geoffroii*) in the south-west of Western Australia | 11 |
| Midwest | Geraldton Sandplains | Rangelands | Monitoring of threatened birds on Dirk Hartog Island | 16 |
| Goldfields | Gascoyne | Rangelands | Rangelands restoration: reintroduction of native mammals to Matuwa (Lorna Glen) | 21 |
| South West | Jarrah Forest | South West, South Coast | South West Threatened Fauna Recovery Project: Southern Jarrah Forest | 14 |
| South Coast | Warren | South Coast | Understanding and reducing python predation of the endangered Gilbert's potoroo | 13 |

# Plant Science and Herbarium

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| 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 | 46 |
| All Regions | All IBRA Regions, All IMCRA Regions | All Regions | Herbarium collections management | 33 |
| All Regions | All IBRA Regions | All Regions | Interactive key and taxonomic studies of Myrtaceae tribe Chamelaucieae | 28 |
| 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 | 42 |

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|---|---|---|---|---|
| Pilbara | Pilbara | Rangelands | Molecular characterisation of stinking passionflower (*Passiflora foetida*) | 27 |
| All Regions | All IBRA Regions | All Regions | Seed biology, seedbank dynamics and collection and storage of seed of rare and threatened Western Australian taxa | 45 |
| All Regions | All IBRA Regions | All Regions | Strategic taxonomic studies in families including Amaranthaceae and Fabaceae (*Ptilotus, Gomphrena, Swainsona*) and other plant groups | 29 |
| All Regions | All IBRA Regions | All Regions | Systematics of the triggerplant genus *Stylidium* | 37 |
| All Regions | All IBRA Regions | All Regions | Taxonomic resolution and description of new plant species, particularly priority flora from those areas subject to mining in Western Australia | 40 |
| Kimberley, Pilbara, Swan, South Coast, South West, Warren | Victoria Bonaparte, Northern Kimberley, Central Kimberley, Dampierland, Gascoyne, Geraldton Sandplains, Swan Coastal Plain, Jarrah Forest, Esperance Plains, Warren | Rangelands, Northern Agricultural, Swan, South West, South Coast | Taxonomic review and floristic studies of the benthic marine algae of north-western Australian and floristic surveys of Western Australian marine benthic algae | 38 |
| All Regions | All IBRA Regions, All IMCRA Regions | All Regions | Taxonomy of selected families including legumes, grasses and lilies | 36 |
| All Regions | All IBRA Regions | All Regions | Taxonomy of undescribed taxa in the Ericaceae subfamily Styphelioideae, with an emphasis on those of conservation concern | 35 |
| All Regions | All IBRA Regions | All Regions | The Western Australian Herbarium specimen database | 31 |
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|---|---|---|---|---|
| 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 | 39 |
| Midwest, Goldfields, Wheatbelt, Swan, South Coast, South West | Gascoyne, Geraldton Sandplains, Avon Wheatbelt, Jarrah Forest, Esperance Plains | Rangelands, Northern Agricultural, Avon, Swan, South West, South Coast | The population ecology of critically endangered flora | 43 |
| Midwest, Wheatbelt, South Coast, South West | Gascoyne, Murchison, Avon Wheatbelt, Coolgardie, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren | Northern Agricultural, Avon, Swan, South West, South Coast | Translocation of critically endangered plants | 41 |

# Ecosystem Science

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| 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 | 61 |

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| Pilbara, Midwest, Goldfields, Wheatbelt, South Coast, South West, Warren | Murchison, Geraldton Sandplains, Avon Wheatbelt, Coolgardie, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren | Wheatbelt, Rangelands, Northern Agricultural, South West, South Coast | Genetic analysis for the development of vegetation services and sustainable environmental management | 63 |
| South West | Swan Coastal Plain, Jarrah Forest | South West | Hydrological function of critical ecosystems | 53 |
| Swan | Jarrah Forest | Swan, South West | Hydrological response to timber harvesting and associated silviculture in the intermediate rainfall zone of the northern jarrah forest | 62 |
| South West | Jarrah Forest | South West | Investigating the causes of change in forest condition | 52 |
| Swan | Swan Coastal Plain | Swan | Lifeplan: A planetary inventory of life | 49 |
| Swan, Warren | Jarrah Forest, Warren | Swan, South West | Long-term stand dynamics of regrowth forest in relation to site productivity and climate | 59 |
| Warren | Jarrah Forest, Warren | South West | Responses of terrestrial vertebrates to timber harvesting in the jarrah forest | 57 |
| All Regions | All IBRA Regions | All Regions | Taxonomy, zoogeography and conservation status of aquatic invertebrates | 55 |
| Kimberley, Wheatbelt, Swan, South Coast, South West, Warren | All IBRA Regions | Wheatbelt, Rangelands, Northern Agricultural, Avon, Swan, South West, South Coast | Tracking the condition of Ramsar wetlands in Western Australia | 50 |
| 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 | 56 |
| Swan, South West, Warren | Jarrah Forest | Swan, South West | Understanding the implications of a drying climate on forest ecosystem function to inform and improve climate change adaptation | 51 |

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| All Regions | All IBRA Regions, All IMCRA Regions | All Regions | Western Australian flora surveys | 58 |
| All Regions | All IBRA Regions, All IMCRA Regions | All Regions | Western Australian wetland fauna surveys | 60 |

# Marine Science

| DBCA Region | IBRA/IMCRA | NRM Region | Project Title | Page |
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| Kimberley | Bonaparte Gulf, Kimberley, Northwest Shelf, Cambridge-Bonaparte, Canning, King Sound | Rangelands | Distribution and abundance estimate of Australian snubfin dolphins at a key site in the Kimberley region, Western Australia | 71 |
| Pilbara | Ningaloo | Rangelands | Do marine reserves adequately represent high diversity cryptobenthic fish assemblages in a changing climate? | 68 |
| Pilbara | Pilbara, Pilbara (Offshore) | Rangelands | Habitat use, distribution and abundance of coastal dolphin species in the Pilbara | 70 |
| All Regions | All IBRA Regions, All IMCRA Regions | All Regions | Marine monitoring program | 75 |
| Kimberley, Pilbara | Northwest Shelf | Rangelands | North West Shelf Flatback Turtle Conservation Program | 76 |
| Pilbara | Pilbara, Pilbara (Nearshore) | Rangelands | Primary productivity and energy transfer between marine ecosystems. | 66 |
| Warren | WA South Coast | South Coast | Spatial and temporal patterns in benthic invertebrate communities of the Walpole and Nornalup Inlets Marine Park | 77 |
| Pilbara | Carnarvon, Pilbara (Nearshore) | Rangelands | The influence of macroalgal fields on coral reef fish | 72 |
| Kimberley | All IMCRA Regions | Cocos Keeling Islands, Rangelands | Understanding movements and identifying important habitats of sea turtles in Western Australia | 74 |

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| Swan, South West | Pilbara, Carnarvon, Yalgoo, Geraldton Sandplains, Swan Coastal Plain, Warren | Rangelands, Northern Agricultural, Swan | Understanding the key ecosystem services provided by the seagrass meadows of Western Australia | 69 |

# Fire Science

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| Swan | Geraldton Sandplains, Swan Coastal Plain | Northern Agricultural, Swan | Evaluation of synergies among fire and weed management in urban biodiversity and fire management | 80 |
| Goldfields, Wheatbelt, South Coast | Yalgoo, Avon Wheatbelt, Coolgardie, Mallee | Wheatbelt, Rangelands | Fire regimes and impacts in transitional woodlands and shrublands | 83 |
| Swan, South West, Warren | Jarrah Forest | South West | Long term response of jarrah forest understorey and tree health to fire regimes | 81 |
| Kimberley | Northern Kimberley | Rangelands | North Kimberley Landscape Conservation Initiative: monitoring and evaluation | 82 |

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| Wheatbelt, Swan, South Coast, South West, Warren | Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren | Northern Agricultural, Avon, Swan, South West, South Coast | Orchid conservation and recovery | 90 |

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# Perth Zoo Science

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| Swan, South West | Swan Coastal Plain, Jarrah Forest | Swan, South West | *Anstisia* frog breed and rear for release program | 97 |
| Swan | Swan Coastal Plain | Swan | Behavioural observations of Perth Zoo collection animals for animal welfare purposes and establishment of baseline data | 96 |
| Midwest, Swan, South Coast | Geraldton Sandplains, Swan Coastal Plain, Jarrah Forest, Esperance Plains | Northern Agricultural, Swan, South Coast | Dibbler breed for release program | 98 |
| Swan | Swan Coastal Plain | Swan | Memory of recent actions in large-brained mammals (*Elephas maximus*) | 95 |
| Wheatbelt, Swan, Warren | Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Warren | Northern Agricultural, Swan, South West | Numbat breed for release program | 99 |
| Swan | Swan Coastal Plain | Swan | Olfactory and auditory based behavioural enrichment for Perth Zoo's Asian elephants | 94 |
| Midwest, Swan, South Coast | Gascoyne, Murchison, Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren | Wheatbelt, Northern Agricultural, Swan, South West, South Coast | Survival and dispersal of black cockatoos in south-west Western Australia | 100 |
| Swan, South Coast | Swan Coastal Plain, Mallee, Esperance Plains | Swan, South Coast | Western ground parrot husbandry | 93 |
| Swan, Warren | Geraldton Sandplains, Swan Coastal Plain, Jarrah Forest, Warren | Swan, South West | Western swamp tortoise breed for release program | 97 |

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| Swan | Swan Coastal Plain | Swan | Using Swan Canning Estuarine Response Model to optimise oxygenation plant efficiency | 101 |

# Remote Sensing and Spatial Analysis

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| Midwest | Yalgoo, Shark Bay | Rangelands | Dirk Hartog Island vegetation monitoring | 121 |
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# Species and Communities

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