

Department of Parks and Wildlife

Science and Conservation Division

annual research report

2013–14



Department of
Parks and Wildlife



DIRECTOR'S MESSAGE

There has been much change since we became the Department of Parks and Wildlife in July 2013, with renewed focus on conservation of Western Australia's unique plants and animals and our world-class network of parks, reserves and natural areas. Our Strategic Directions for 2013-14 recognised that science and research play a critical role in effective management of species and ecosystems.

In October 2013 the Science Division was amalgamated with the Nature Conservation Division providing new opportunities for science to more directly inform conservation policy and management, and for management requirements and knowledge gaps to set research priorities.

While much of our work supports the conservation priorities of the Wildlife corporate goal, we also provide scientific research and information to support delivery of the Parks, Fire, Managed Use and People corporate goals. The combined responsibilities of the divisions are focused around two main areas of Species conservation and Landscape conservation. Our work in species conservation involves activities, such as species and community recovery, wildlife protection and licensing, understanding species biology and taxonomy, while our landscape conservation work is focused on landscape and seascape management, development advice and liaison, understanding ecosystem processes and biological survey. Information systems and monitoring and evaluation link across both species and landscape conservation activities. Across all areas, effective exchange of knowledge and information to support legislation and policy is fundamental to effective delivery of wildlife management outcomes.

Partnerships have always been an important means of achieving our outcomes. In delivering against the priorities encapsulated in the corporate goals we continue to work with other Divisions, particularly Forest and Ecosystem Management, Parks and Visitor Services, Regional and Fire Management Services and Public Information and Corporate Affairs. We also seek to engage with our partners, including other research institutions, industry, Aboriginal people, the community and other government agencies.

In addition to broader structural change, there has been some internal restructure leading to several changes to science program structures and names, to reflect the broader context of the new Division. The Fauna Conservation and Flora Conservation and Herbarium programs are now known as the Animal Science Program and the Plant Science and Herbarium Programs, and the Landscape Conservation program is known as the Ecosystems Science Program. The Science Applications Program is now called the Ecoinformatics program due to its focus on informatics for ecological systems.

The hydrology and recovery catchment work undertaken in the former Nature Conservation Division has been combined with the wetlands survey and monitoring undertaken in Science Division to form the Wetlands Conservation Program. Adrian Pinder was appointed as Program Leader and is developing an integrated approach to biological and hydrological wetland science. Revegetation systems research is winding down with the completion of the Future Farm Industries Co-operative Research Centre. The work in this area that was undertaken in the Natural Resources Branch in the former Nature Conservation Division has been integrated with other revegetation research undertaken in the Ecosystem Science Program.

We decided to disband the Biodiversity and Climate change Unit, which was set up in 2008 as a cross program unit to provide a focus for climate change research. Climate change is now integrated into much of the research work across the programs and there is no longer a need to have a specific focus on it, as it is one of many threatening processes.

There have also been more recent changes to programs since 2013-14 with Dr Lesley Gibson appointed as Program Leader of the Biogeography Program and Dr Alan Kendrick appointed as Program Leader of the Marine Science Program. Dr Stephen van Leeuwen has relinquished the Biogeography Program Leader role to focus on an expanded role as Partnerships Manager for the Science and Conservation Division. This includes a focus on engagement with Aboriginal people, particularly in the context of amendments to the CALM Act and the requirements for the department to enter into joint management arrangements.

This report provides accountability for the research activity undertaken in the Science and Conservation Division and is based on a level of technical content to provide that accountability. We recognise the importance of effective communication of the outcomes of our research, particularly in ensuring the results inform conservation policy and wildlife and forest management practice. Therefore, this year we have also produced a series of non-technical publications that describe the science we are undertaking in each of the regions of the Department. These 'Science in the Regions' publications summarise the science activities we are undertaking to support conservation and wildlife management in each region. They are available on the website along with a copy of this report.

I look forward to continuing to work effectively with all our partners in delivery of our core objectives to provide effective science to inform conservation and management of our plants, animals and ecosystems, and to support effective management of our parks and reserves, delivery of our fire program, managed use of our natural resources and science stories that inspire and engage people with our natural heritage.

Dr Margaret Byrne
Director Science and Conservation
August 2014

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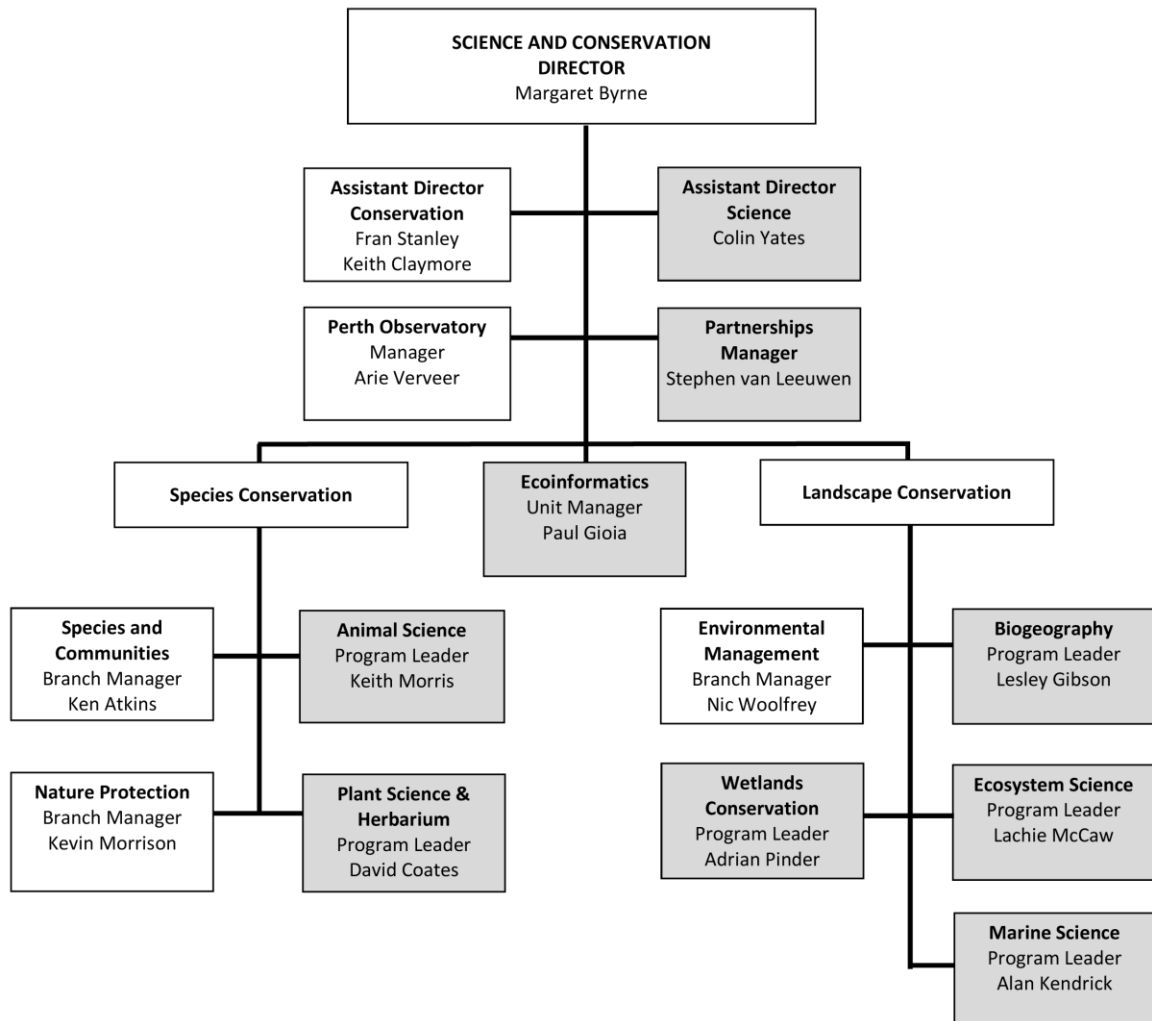
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SCIENCE DELIVERY STRUCTURE



The Department of Parks and Wildlife is a science based organisation where science provides the knowledge and information to support the Department's corporate objectives and priorities for wildlife management, parks management, fire management and managed use.

The science function (shaded in structure diagram) of the Science and Conservation Division is integrated with policy and management functions reflecting the vital role of science and information in effectively managing Western Australia's plants, animals and ecosystems, and in the sustainable development of the State.

Scientific knowledge forms a framework for engagement with the community in appreciating our natural places and with Aboriginal people on Country.

Western Australia is a large state with unique biological diversity and the explicit knowledge required to manage Western Australia's unique environments requires local expertise. Parks and Wildlife's internal research capacity is extended and leveraged through attracting external investment to address Departmental priorities, and through strategic collaborations and partnerships.

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CURRENT COLLABORATION WITH ACADEMIA (STUDENT PROJECTS)

DPaW Officer	Student	Project Title	Degree / Level	Duration	University Academic	University
D Algar	K Koch	Genetic diversity and phylogeography of Australian cats	PhD	2009–2012	Dr K Schwenk	Johann Wolfgang Goethe University
D Algar	N Dybing	Parasites and diet of feral cats and rodents on mainland Western Australia and offshore Islands (Christmas Island and Dirk Hartog Island)	PhD	2012–2014	Dr P Adams	Murdoch University
N Burrows	M Wysong	The ecology and interactions of dingoes and feral cats in the arid Rangelands of Western Australia	PhD	2012–2015	Prof R Hobbs, Dr E Ritchie	The University of Western Australia
R Butcher, K Thiele, M Byrne	E Joyce	Investigation of taxonomic boundaries in the <i>Tetratheca hirsuta</i> Lindl. complex	BSc (Honours)	2013–2014	Prof P Grierson	The University of Western Australia
M Byrne	J Moniodis	The genetics, essential oil composition and factors controlling the biosynthesis of sesquiterpenes in Western Australian sandalwood	PhD	2010–2014	Dr J Plummer, Dr L Barbour	The University of Western Australia
M Byrne, D Coates	H Nistelberger	Ancient, terrestrial islands in a semi-arid landscape: patterns of genetic diversity in regional endemics of the Yilgarn Banded Iron Formations	PhD	2010–2014	Dr D Roberts	The University of Western Australia
D Coates	C Allen	Factors that affect seedling establishment and the implications for the translocation of species at risk of extinction	PhD	2010–2014	A/Prof P Poot, A/Prof M Moody, A/Prof R Standish	The University of Western Australia
K Friedman	A Swarts	How best can managers measure on-going change in coral condition and related pressure metrics at sites where there is high levels of human use?	BSc (Honours)	2012–2013	Dr M O'Leary	Curtin University of Technology
A Friend	J Austen	Trypanosomes of some Western Australian mammals: phylogenetics	PhD	2006–2012	Dr U Ryan	Murdoch University
C Gosper	B Lake	Fire regime responses of biological soil crusts in eucalypt woodlands of south-west Australia	PhD	2013–	Dr P Grierson	The University of Western Australia

DPaW Officer	Student	Project Title	Degree / Level	Duration	University Academic	University
J Huisman	R Dixon	Systematics of <i>Sargassum</i> (Phaeophyceae) in Australia	PhD	2008–2012	J Huisman	Murdoch University
G Keighery	T Hevroy	Molecular taxonomy, phylogeography and population genetics of the <i>Grevillea thelemanniana</i> complex	PhD	2010–2012	A/Prof M Moody, Dr S Krauss	The University of Western Australia
A Kendrick	F Vitelli	Feeding ecology of Pomacentridae and its ecological role in fish herbivory in temperate algal-dominated reefs	PhD	2012–2013	A/Prof G Hyndes	Edith Cowan University
A Kendrick	A Turco	The role of <i>Kyphosus</i> spp. in reef ecosystems	PhD	2012–2015	A/Prof G Hyndes	Edith Cowan University
L McCaw	M Peace	Fire weather	PhD	2010–2014	Dr T Mattner, Dr G Mills, Dr J Keppert	Adelaide University, Centre for Australian Weather and Climate Research
K Morris	K Bettink	Ecology and taxonomic differentiation in the Australian water rat and implications for its conservation status in Western Australia	PhD	2010–2014	Dr H Mills	The University of Western Australia
K Morris	R Thavornkanlapachai	Genetic consequences of mammal translocations in Western Australia using case studies of dighters, boodies and black-flanked rock wallabies	PhD	2011–2014	Dr H Mills	The University of Western Australia
K Morris	J Dunlop	Factors affecting fauna translocation success	PhD	2010–2013	Prof A Thompson	Murdoch University
A Pinder	D Quek	Breeding systems and phylogeography of selected saline lake invertebrates	PhD	2013–	Dr J Chaplin	Murdoch University
A Pinder	J Lizamore	Nutrient movement and its impact on aquatic invertebrates as a food source of waterbirds between different wetland suites within the Lake Warden Wetland System	PhD	2013–	Dr R Vogwill	The University of Western Australia
S van Leeuwen	J Harvey	Regional variability in salmon gum communities in the Great Western Woodlands	MSc	2011–2013	Dr R Harris, Prof L Mucina, Dr S Prober	Curtin University, CSIRO
A Wayne	G Yeatman	Wildlife ecology in the southern jarrah forest	PhD	2011–2014	Dr H Mills	The University of Western

DPaW Officer	Student	Project Title	Degree / Level	Duration	University Academic	University
						Australia
A Wayne	A Worth	The role of <i>Toxoplasma gondii</i> in declining populations of the woylie (<i>Bettongia penicillata ogilbyi</i>)	PhD	2011–2013	Prof A Thompson, A/Prof A Lymbery, Dr T Fleming	Murdoch University
A Wayne	M Pleitner	An exploration of the associations between the population decline of <i>Bettongia penicillata ogilbyi</i> (Gray, 1837) and field health assessment data from the Upper Warren region Western Australia	BSc (Honours)	2014–2014	Dr D Mahsberg	Julius-Maximilians Universität Würzburg, Germany
A Wayne	U Parkar	Genetic diversity of <i>Blastocystis</i> isolates found in West Australian native fauna	PhD	2013–2014	Prof A Thompson	Murdoch University
A Wayne	S Hing	Stress and disease in critically endangered woylies (<i>Bettongia penicillata</i>)	PhD	2014–2014	Prof A Thompson, Dr S Godfrey	Murdoch University
A Wayne	A Botero	Diversity of trypanosomes infecting Western Australian marsupials: virulence and pathogenicity	PhD	2010–2014	Prof A Thompson	Murdoch University
A Wayne	K Jones	Pathogen transmission in the critically endangered woylie: a community, population, and individual approach	PhD	2014–2017	Prof A Thompson, Dr S Godfrey	Murdoch University
A Wayne	A Northover	The ecology of parasite transmission in fauna translocations	PhD	2014–2017	Prof A Thompson	Murdoch University
A Wayne	C Thompson	Trypanosome polyparasitism and the decline of the critically endangered Australian potoroid, the brush-tailed bettong (<i>Bettongia penicillata</i>)	PhD	2010–2014	Prof A Thompson	Murdoch University
A Wayne	Z Lim	Histopathological review of the causes of death in Woylies (<i>Bettongia penicillata</i>) presented to Murdoch University for necropsy in the last 10 years, with special focus on (possible) <i>Trypanosoma</i> related histopathology.	PhD	2014–2016	Prof A Thompson, Dr S Godfrey	Murdoch University
A Wayne	K Skogvold	A comparative health and disease investigation in	PhD	2010–2014	Dr K Warren, Dr S Vitali, Dr C	Murdoch University

DPaW Officer	Student	Project Title	Degree / Level	Duration	University Academic	University
		the woylie: captive vs free-range enclosure vs wild			Holyoake, Dr C Monaghan	
A Wayne	K Bain	Ecological study of the quokka (<i>Setonix brachyurus</i>) in the southern forests of south-west Western Australia	PhD	2006–2014	A/Prof R Bencini	The University of Western Australia
A Wayne	H Burmej	Ectoparasites of threatened mammals in Western Australia: biodiversity and impact	PhD	2007–2014	Prof A Thompson, Dr A Smith	Murdoch University
S Whiting	J Tedeschi	Assessing the resilience of marine turtle embryos to extreme temperatures	PhD	2011–	Dr N Mitchell, Dr O Berry, Dr M Meekan	The University of Western Australia, Australian Institute of Marine Science, CSIRO
S Whiting	X Hoenner	The nesting and post-nesting ecology of hawksbill turtles in northern Australia	PhD	2009–2012	Dr C McMahon	Charles Darwin University
S Whiting	B Bentley	Predicting the effect of climate change on embryonic flatback (<i>Natator depressus</i>) and green (<i>Chelonia mydas</i>) sea turtles in the Kimberley region of Western Australia	BSc (Honours)	2014–2017	Dr N Mitchell, Dr J Kennington, Dr O Berry	The University of Western Australia
S Whiting	J Stubbs	Assessing the resilience of marine turtle embryos to extreme temperatures	PhD	2011–	Dr N Mitchell	The University of Western Australia
S Whiting	N Robson	Optimal release locations and timing for rehabilitated sea turtles using a decision support system	BSc (Honours)	2014–	Dr M Thums, Dr C Pattiaratchi	The University of Western Australia
S Wilson	I Lim	How does a seaweed-associated reef fish respond to seasonal habitat loss?	BSc (Honours)	2014–	Dr C Fulton	Australian National University
S Wilson	J Goetze	Variation in the intensity of periodic harvests in Fijian tabu areas and the effect on reef fish assemblages	PhD	2012–2015	Dr T Langlois	The University of Western Australia
S Wilson	E Thillainath	Quantifying the role of mesopredatory fish in coral reef food webs	BSc (Honours)	2013–2014	Dr J McIlwain	Curtin University
S Wilson	E Ashworth	Quantitative diet analysis of four mesopredators from Ningaloo Reef, Western Australia	PhD	2012–	Dr C Boudouresque	Aix-Marseille University, France

DPaW Officer	Student	Project Title	Degree / Level	Duration	University Academic	University
C Yates	A Williams	Climate change impacts on the northern sandplain kwongan vegetation of south-western Australia	PhD	2010–2013	Dr N Enright	Murdoch University
C Yates	A Cochrane	Population variation in seed and seedling traits along a climate gradient in south-west Western Australia	PhD	2010–2013	Dr AB Nicotra	Australian National University

EXTERNAL PARTNERSHIPS

Partnership name	Project Title	External Funding	DPaW Involvement
ARC Linkage, Australian National University, CSIRO, Alcoa	Genomics for climate adaptation in <i>Eucalyptus</i> foundation species	\$375K for 2013–2016	M Byrne
ARC Linkage, Australian National University, WA Museum, SA Museum	Phylogenomic assessment of conservation priorities in two biodiversity hotspots: the Pilbara and the Kimberley	\$570K for 2012–2015	M Byrne, D Coates
ARC Linkage, Karara Mining Ltd, The University of Western Australia	Managing genetic diversity and evolutionary processes in foundation species for landscape restoration in the midwest of Western Australia	\$527K for three years	D Coates, M Byrne, M Millar
ARC Linkage, The University of Western Australia	Automation of species recognition and size measurement of fish from underwater stereo-video imagery	\$436K over three years, \$190K cash and in kind from partner organisations	S Wilson
ARC Linkage, The University of Western Australia, Chevron, Rio Tinto Iron Ore, Botanic Parks and Gardens Authority	Defining biologically significant units in spinifex (<i>Triodia</i> spp.) for improved ecological restoration in arid Australia	\$549K over four years	K Thiele, S van Leeuwen
ARC Linkage, University of Sydney, Department of Society, Environment Water Population and Communities, Australian Reptile Park	Predicting the ecological impact of cane toads on native fauna of north western Australia	\$503K for three years	D Pearson
Atlas Iron	Ecology and management of the Pilbara leaf-nosed bat	\$350K	S van Leeuwen, L Gibson, K Morris
Atlas Iron	Investigating the interactions between feral predators in the Pilbara	\$300K	K Morris, S van Leeuwen, J Dunlop
Atlas Iron	Sponsorship of the 'Research directions for Pilbara leaf-nose bat' workshop	\$10K	S van Leeuwen, K Morris, L Gibson
Atlas Iron (Mt Dove Offset), CSIRO Ecosystem Sciences	Strategic weed assessment for the Chichester subregion of the Pilbara	\$100K	S van Leeuwen
Atlas Iron, Fortescue Metals Group, Main Roads Western Australia	Ecology and management of the northern quoll in the Pilbara	Atlas: \$50K (2010–2016), Fortescue: \$100K (2012–2021), Main Roads: \$25K	K Morris, S van Leeuwen, J Dunlop
Atlas Iron, Pilbara Corridors, Rangelands NRM, CSIRO Ecosystem Sciences	Strategic weed risk assessment and implementation plan for the Chichester and Fortescue subregions of the Pilbara	\$385K	S van Leeuwen
Atlas of Living Australia, Centre for Biological Information Technology, The University of Queensland	IdentifyLife, a new platform for collaborative development of identification tools	\$57K p.a. for four years	K Thiele

Partnership name	Project Title	External Funding	DPaW Involvement
Australian Biological Resources Study	Bush Blitz: ex-Credo Station survey	\$8K	M Cowan, S van Leeuwen, N Gibson, M Langley, N Guthrie
Australian Biological Resources Study	Bush Blitz: Cane River Conservation Park survey	\$4K	M Cowan, S van Leeuwen, A Markey, S Dillon
Australian Centre for Ecological Analysis and Synthesis	Using plant functional traits to predict ecosystem vulnerability to changing fire regimes	Nil	C Gosper
Australian Institute of Marine Science	Coral reef fish recruitment study	AIMS funded field trip	S Wilson, T Holmes
Australian Institute of Marine Science, Australian National University, The University of Western Australia	Ningaloo seasonal seaweeds	\$30K	S Wilson, K Murray, T Holmes
Australian Institute of Marine Science, CSIRO Marine and Atmospheric Research, Department of Fisheries	Temporal and spatial variation in coral cover on Western Australian reefs	Nil	S Wilson, G Shedrawi, K Friedman, K Bancroft, C Nutt, S Field
Australian Wildlife Conservancy	Establishment of translocated populations of critically endangered <i>Acacia imitans</i> and <i>A. unguicula</i>	AWC provides ongoing care and maintenance	L Monks
BHP Billiton Iron Ore	Identification Botanist position at the Western Australian Herbarium	\$105K	K Thiele
BHP Billiton Iron Ore, Fortescue Metals Group (Cloudbreak Stage B Mine Offset)	Floristic survey of the Fortescue Marsh	\$45K, \$200K	S van Leeuwen, C McCormick, M Lyons, A Markey
BHP Billiton Iron Ore, Main Roads Western Australia	Ecology and management of Pilbara olive python in the Pilbara	BHP Billiton: \$50K, Main Roads: \$50K	D Pearson, S van Leeuwen
Biodiversity Fund, Warren Catchment Council, CSIRO	Restoring natural riparian vegetation systems previously infested by blackberry along the Warren and Donnelly Rivers	\$2,945K for 2011–2017	M Byrne
Bushfire CRC	Bushfire occurrence and fire growth modelling	Nil	L McCaw
CSIRO Ecosystem Sciences	Cost-effective conservation decisions to mitigate threats to Pilbara biodiversity	Nil	S van Leeuwen
CSIRO Ecosystem Sciences	Biodiversity modelling for BHP Billiton Iron Ore's Strategic Environmental Assessment in the Pilbara	Nil	S van Leeuwen
CSIRO Ecosystem Sciences	Pilbara biological survey biodiversity GDM modelling/gap analysis: terrestrial fauna and wetland flora and fauna	Nil	A Pinder, N McKenzie, L Gibson, M Lyons, AH Burbidge

Partnership name	Project Title	External Funding	DPaW Involvement
CSIRO Ecosystem Sciences, Koolan Island Mining (Koolan Island Mine Offset)	Invasive <i>Passiflora foetida</i> in the Kimberley and Pilbara: understanding the threat and exploring solutions	Nil, \$100K	S van Leeuwen
CSIRO Land and Water	Pilbara groundwater dependant ecosystem study	Nil	S van Leeuwen, A Pinder
CSIRO Marine and Atmospheric Research	What is the role of predators at Ningaloo and how are they impacted by human use?	\$55K in kind (2009–2012)	S Wilson, T Holmes
CSIRO and independent scientists	Explaining and predicting the occurrence of night parrots (<i>Pezoporus occidentalis</i>) using GIS and ecological modelling	\$38K	AH Burbidge
Caring for our Country	Identifying threats to marine biodiversity of the Ningaloo World Heritage Area: deeper water fish community surveys within the Ningaloo Marine Park	\$65K	T Holmes
Caring for our Country	Western Desert fire project	\$317K over two years	N Burrows, G Behn, C Rummery
Caring for our Country	Eradication of exotic rodents from six islands of high conservation value	\$890K 2010–2013	K Morris, R Palmer
Central Desert Native Title Service	Biological survey of the Birrilburru Indigenous Protected Areas: phase 1 - Carnarvon Range	\$25K	S van Leeuwen, K Quinlan, M Langley, N Gibson, M Cowan, N Guthrie, A Pinder, L Gibson
Chevron (Gorgon Gas Development, Net Conservation Benefit funding)	Cat eradication on Dirk Hartog Island	\$200K p.a. for five years	D Algar, M Onus, J Rolfe
Chevron (Gorgon Gas Development, Offsets Program)	Translocations of mammals from Barrow Island: offset program	ca. \$1.4M p.a. 2009–2014, \$500K p.a. 2015–2019	K Morris, N Thomas, K Rayner, J Angus, B Johnson, B Muir, S Garretson
DSE (Victoria) and Department of Sustainability, Environment Water Population and Communities (DSEWPaC)	PAPP toxicosis and cat bait pellet development	\$250K DSEWPaC to DSE	D Algar
Department of Sustainability, Environment, Water, Population and Communities	Western Australian black spot biological survey campaign	\$136K	S van Leeuwen, L Gibson, M Cowan, N Gibson
Edith Cowan University	Spatial and temporal patterns in benthic invertebrate communities of the Walpole and Nornalup Inlets Marine Park	Nil	A Kendrick, M Rule
Edith Cowan University	Monitoring movement patterns of marine fauna using Vemco VRAP Acoustic tracking system	Nil	A Kendrick, S Wilson
Fortescue Metals Group (Main Line Duplication Offset), Millennium Minerals	Ecology and management of bilby in the Pilbara	\$100K (2012–2021), \$60K (2012–2017)	K Morris, S van Leeuwen, M

Partnership name	Project Title	External Funding	DPaW Involvement
(Golden Eagle Offset)			Dziminski
Fortescue Metals Group (Main Line Duplication Offset), Millennium Minerals (Golden Eagle Offset)	Bilby conservation and management in the Pilbara	\$100K (2012–2021), \$60K (2012–2017)	K Morris, M Dziminski
Fortescue Metals Group (Solomon, Rail Duplication, Christmas Creek Water Management Offset)	Landscape scale management in the central Pilbara	\$53K	S van Leeuwen
Fortescue Metals Group Ltd (Christmas Creek Water Management Offset)	Baiting feral cats on the Fortescue Marsh	\$600K	D Algar, S van Leeuwen, N Hamilton
Future Farm Industries CRC	Management of weed and genetic risk in perennial landuse systems	\$257K for 2011–2014	M Byrne, B Macdonald
Main Roads Western Australia	Ecology and management of northern quoll in the Pilbara	\$25K	K Morris, A Cook
Millennium Seedbank Project	Seed collection, storage and biology	\$128K p.a. to 2011, \$8K in 2012–2013	A Cochrane, D Coates
Murdoch University	Taxonomic studies of Western Australian marine plants	\$40K p.a. 2011–2013	J Huisman
Murdoch University (Centre for Fish, Fisheries & Aquatic Ecosystems Research), Caring for our Country	Fish populations and invasive species of Vasse-Wonnerup Ramsar Site	\$215K	J Lane, A Clarke
Murdoch University (Centre for Fish, Fisheries & Aquatic Ecosystems Research), South West Catchments Council	Fishes and invertebrates of the Vasse-Wonnerup Ramsar Site	\$14K in 2012–2013	J Lane, A Clarke
Murdoch University, School of Biological Sciences	Genetic studies of Pilbara EPBC Act listed vertebrate fauna	Nil	K Morris, D Pearson, S van Leeuwen
Murdoch University; Perth Zoo; Department of Environment and Heritage (SA); University of Western Australia	Woylie conservation research project	Nil	A Wayne, C Vellios, C Ward, M Maxwell
National Climate Change Adaptation Research Facility, Monash University, Griffith University, South Australian Research and Development Institute, Department of Environment and Resource Management (Qld), Natural Resources, Environment, the Arts and Sport (NT)	Building the climate resilience of arid zone freshwater biota: identifying and prioritising processes and scales for management	\$426K	A Pinder, K Quinlan
National Climate Change Adaptation Research Facility, Murdoch University, The University of Western Australia, Department of Water and CSIRO.	A risk assessment and decision framework for managing groundwater dependent ecosystems with declining water levels	\$325K	A Pinder, M Penniford
National Science Foundation (US)	Systematics and Biogeography of the Inocybaceae	\$19K	N Bougher
North Australian Marine Research Alliance	Assessing spatial and demographic structure of anthropogenic mortality on Australasian marine turtles	\$300K (2012–2014)	S Whiting

Partnership name	Project Title	External Funding	DPaW Involvement
Office of the Environmental Protection Authority, Terrestrial Ecosystems Branch	A review of subterranean fauna assessment in Western Australia	Nil	S van Leeuwen, A Pinder
Rangelands Natural Resource Management - Pilbara Corridors	Biodiversity assets and landscape-scale management of the Fortescue River catchment	Nil	S van Leeuwen, K Morris
Rhodes College TN, St John's University NY	Phylogenetics and floral symmetry development of the core Goodeniaceae	Nil	K Shepherd
Rio Tinto	Identification Botanist position at the Western Australian Herbarium	\$114K	K Thiele
Rio Tinto Iron Ore (Mesa A Environmental Offsets)	Resolving the systematics and taxonomy of <i>Tephrosia</i> in Western Australia	\$254K (2011–2014)	R Butcher, S van Leeuwen, K Thiele
Rio Tinto Iron Ore (West Angelas Coondewanna West Environmental Offsets)	Fire-mulga study: post-burn monitoring and tussock grassland survey of the Hamersley Range	Nil	S van Leeuwen, N Guthrie
Rio Tinto Iron Ore, BHP Billiton	Seed collection zones for the Pilbara	\$400K	M Byrne, S van Leeuwen, D Coates
Roy Hill (Roy Hill Mine Offset)	Jartaku bilby enclosure proposal	\$58K	K Morris, S van Leeuwen, M Dziminski, M Cowan
Royal Botanical Gardens, Melbourne	Molecular assessment of morphological species of <i>Cortinarius</i> (Fungi) as used in field surveys by analysis of the ITS barcode region	\$2.1K	R Robinson
Satterley Property Group	Factors associated with western ringtail possum (<i>Pseudocheirus occidentalis</i>) persistence within retained habitat at development sites	\$400K (2009–2013)	K Morris
Shire of Christmas Island, Christmas Island National Park	Christmas Island cat and rat management plan (stage 2B)	\$450K	D Algar, N Hamilton
South Coast Natural Resource Management	Great Western Woodland vegetation map reconciliation project	\$100K	S van Leeuwen, R Coppen, C Bishop, B Bayliss
South Coast Natural Resource Management, Caring for Our Country, DPaW South Coast Region	Increasing native habitat through protection of EPBC species and ecological communities (dibbler recovery)	\$30K (2011–2013)	A Friend
State NRM	Fast track critically endangered flora recovery	\$1.6M (2013–2015)	D Coates
Terrestrial Ecosystem Research Network (TERN)	TERN: ecoinformatics facility and development of ecological databases and portals	Nil	P Gioia

Partnership name	Project Title	External Funding	DPaW Involvement
Terrestrial Ecosystem Research Network (TERN)	TERN multiscale plot network: AusPlot Rangelands and SWATT	\$250K for SWATT, \$90K for AusPlots Rangelands	S van Leeuwen, N Casson, R Meissner, R Coppen
The University of Western Australia	Genetic diversity of corals in the Montebello and Barrow Islands MPAs	Nil	S Field
The University of Western Australia	Assessing fish communities in Shoalwater Islands Marine Park	Nil	K Friedman, A Kendrick, S Wilson, M Rule, K Bancroft, T Holmes
The University of Western Australia	Assessing fish communities in Marmion Marine Park	Nil	K Friedman
The University of Western Australia Centre of Excellence for Environmental Decisions	Susceptibility of frogs to declining rainfall in a biodiversity hotspot	Nil	M Cowan
The University of Western Australia Centre of Excellence for Environmental Decisions	Assessing the vulnerability of honey possums to climate change and habitat disturbances in south-western Australia	Nil	M Cowan
The University of Western Australia, Ecosystem Research Group	Age structure of <i>Callitris</i> in the Carnarvon Range	Nil	S van Leeuwen, M Langley, N Gibson
University of Adelaide	Wetland monitoring program: rotifer and cladoceran identifications	Nil.	A Pinder, D Cale
University of Melbourne, Quantitative and Applied Ecology Group	Species distribution modelling in the Pilbara	Nil	S van Leeuwen
University of Michigan Department of Ecology & 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 Western Australia, Australian Institute of Marine Science, Pendoley Environmental Pty Ltd, AATAMS, Charles Darwin University	Understanding the early offshore migration patterns of turtle hatchlings and the effects of anthropogenic light: a pilot study	\$188,795	S Whiting
WAMSI Kimberley Node 1.2.2	WAMSI Project 1.2.2. Key biological indices required to understand and manage nesting sea turtles along the Kimberley coast	\$1200K	S Whiting, T Tucker
Warren Catchments Council, Caring for our Country	Using well managed habitat to rescue woylies from the brink of extinction	\$150K over three years (2010–2013)	A Wayne, C Vellios, C Ward, M Maxwell
Western Australian Museum	Pilbara biological survey	Nil	A Pinder, L Gibson, M Lyons, AH Burbidge, N McKenzie
Western Australian Museum	NatureMap: data sharing and	Nil	P Gioia

Partnership name	Project Title	External Funding	DPaW Involvement
	joint custodianship		
Western Australian Museum	Kimberley island biodiversity asset identification	Nil	L Gibson, R Palmer
Woodside Energy	Taxonomic studies on Burrup flora	\$120K	R Butcher, S van Leeuwen, K Shepherd, J Wege

SUMMARY OF RESEARCH PROJECT LOCATIONS BY PROGRAM

DPaW Region	IBRA/IMCRA	NRM Region	Project Title	Page
BIOGEOGRAPHY				
South Coast	Mallee, Esperance Plains	South Coast	Biological survey of the Ravensthorpe Range	42
All DPaW Regions	All IBRA Regions	All NRM Regions	Development of ethically acceptable techniques for invertebrate wet-pit trapping	41
Kimberley	Victoria Bonaparte, Northern Kimberley, Dampierland	Rangelands	Kimberley islands biological survey	42
All DPaW Regions	All IBRA Regions	All NRM Regions	Oligochaete taxonomy	44
Pilbara	Pilbara	Rangelands	Pilbara regional biological survey	43
Goldfields, Wheatbelt, South Coast, Warren	Murchison, Avon Wheatbelt, Jarrah Forest, Mallee, Esperance Plains	Wheatbelt, Rangelands, South Coast	South-Western Australia Transitional Transect (SWATT)	36
All DPaW Regions	All IBRA Regions	All NRM Regions	Western Australian flora surveys	37
All DPaW Regions	All IBRA Regions	All NRM Regions	Western Australian terrestrial fauna surveys	39
All DPaW Regions	All IBRA Regions	All NRM Regions	Western Australian wetland fauna surveys	40
ANIMAL SCIENCE				
			Barrow Island Threatened and Priority fauna species translocation program	52
Midwest	Carnarvon, Yalgoo	Rangelands	Cat Eradication on Dirk Hartog Island	46
Pilbara	Pilbara	Rangelands	Conservation and management of the bilby (<i>Macrotis lagotis</i>) in the Pilbara	49
South Coast, Warren	Jarrah Forest, Esperance Plains, Warren	South West, South Coast	Conservation of south coast threatened birds	55
Goldfields, Swan	Coolgardie, Swan Coastal Plain	Rangelands, Swan	Conservation of the graceful sun-moth	57
Pilbara	Pilbara	Rangelands	Decision support system for prioritising and implementing biosecurity on Western Australia's islands	48
Pilbara, Midwest, South	Carnarvon, Gibson Desert, Gascoyne, Murchison	Rangelands, Swan	Development of effective broad-scale aerial baiting strategies for the control of feral cats	62

DPaW Region	IBRA/IMCRA	NRM Region	Project Title	Page
Coast				
Pilbara	Pilbara	Rangelands	Ecology and management of the northern quoll in the Pilbara	56
Wheatbelt	Mallee	Wheatbelt	Factors affecting fauna recovery in the Wheatbelt: Lake Magenta and Dunn Rock Nature Reserves	59
Pilbara, Swan	Pilbara, Swan Coastal Plain, Jarrah Forest	Rangelands, Swan	Genetic approaches for evaluating the contribution of the reserve system to fauna conservation	51
Kimberley, Pilbara	Northern Kimberley, Central Kimberley, Dampierland, Pilbara	Rangelands	Genetic assessment for conservation of rare and threatened fauna	50
South Coast	Jarrah Forest	South Coast	Gilbert's potoroo (<i>Potorous gilbertii</i>) recovery plan	64
Warren	Jarrah Forest	South West	Identifying the cause(s) of the recent declines of woylies in south-west Western Australia	58
Kimberley	Victoria Bonaparte, Northern Kimberley, Ord Victoria Plain, Central Kimberley	Rangelands	Impact of cane toads on biodiversity in the Kimberley	62
All DPaW Regions	Gascoyne	All NRM Regions	Improving the use of remote cameras as a survey and monitoring tool	47
Goldfields	Gascoyne	Rangelands	Rangelands restoration: reintroduction of native mammals to Lorna Glen (Matuwa)	53
Wheatbelt	Avon Wheatbelt	Wheatbelt	Sustained fauna recovery in a fragmented landscape (Dryandra Woodland and Tutanning Nature Reserve)	60
Swan, South West	Jarrah Forest	Wheatbelt, Swan, South West	The importance of fox, cat and native predator interactions to sustained fauna recovery in the northern jarrah forest: is there a mesopredator release effect?	61
PLANT SCIENCE AND HERBARIUM				
South Coast, South West	Swan Coastal Plain, Jarrah Forest, Esperance Plains	Wheatbelt, Swan, South West, South Coast	An investigation of the epidemiology and use of novel phosphite application techniques in <i>Phytophthora cinnamomi</i> infestations in the national parks of the South Coast Region of Western Australia	86
Midwest	Yalgoo	Northern Agricultural	Assessment of genetic diversity, key population processes and evolutionary relationships in the banded iron formation endemic <i>Acacia woodmaniorum</i> and its close relatives	77
All DPaW Regions	All IBRA Regions, All IMCRA Regions	All NRM Regions	Australian wattle identification	95
All DPaW Regions	All IBRA Regions	All NRM Regions	Biodiversity informatics at the Western Australian Herbarium	73

DPaW Region	IBRA/IMCRA	NRM Region	Project Title	Page
All DPaW Regions	All IBRA Regions, All IMCRA Regions	All NRM Regions	Biosystematics of fungi for conservation and restoration of Western Australia's biota	67
Midwest	Geraldton Sandplains	Northern Agricultural	Climate change risks for biodiversity and ecosystem function in species-rich shrublands	68
South Coast	Esperance Plains, Warren	South Coast	Comparison of plant canker pathogen impact and climatic variables in Proteaceae on the south coast of Western Australia and evaluation of selected fungicides as a management tool for canker control in the declared rare flora <i>Banksia verticillata</i> and <i>Lambertia orbifolia</i>	81
All DPaW Regions	All IBRA Regions, All IMCRA Regions	All NRM Regions	Conservation status and systematics of Western Australian <i>Acacia</i>	89
All DPaW Regions	All IBRA Regions, All IMCRA Regions	All NRM Regions	Development of interactive identification platforms and content	88
Wheatbelt	Avon Wheatbelt, Swan Coastal Plain	Northern Agricultural, Avon, Swan, South Coast	Genetic and ecological viability of plant populations in remnant vegetation	89
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	96
All DPaW Regions	All IBRA Regions, All IMCRA Regions	All NRM Regions	Herbarium collections management	72
			Interactive key and taxonomic studies of Myrtaceae tribe Chamelaucieae	66
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	92
Kimberley, Pilbara	Victoria Bonaparte, Northern Kimberley, Ord Victoria Plain, Central Kimberley, Dampierland, Great Sandy Desert, Carnarvon, Little Sandy Desert, Gibson Desert, Gascoyne, Central Ranges	Rangelands	Resolving the systematics and taxonomy of <i>Tephrosia</i> in Western Australia	79
All DPaW Regions	Great Sandy Desert, Carnarvon, Gascoyne, Geraldton Sandplains, Avon Wheatbelt, Coolgardie, Swan Coastal Plain, Jarrah Forest, Hampton, Mallee, Esperance Plains, Warren	Rangelands, Northern Agricultural, Avon, Swan, South West, South Coast	Seed biology, seedbank dynamics and collection and storage of seed of rare and threatened Western Australian taxa	94
All DPaW Regions	All IBRA Regions	All NRM Regions	Strategic taxonomic studies in families including Amaranthaceae and Fabaceae (<i>Ptilotus</i> , <i>Gomphrena</i> , <i>Swainsona</i>) and	69

DPaW Region	IBRA/IMCRA	NRM Region	Project Title	Page
			other plant groups	
Wheatbelt, Swan, South Coast, South West, Warren	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Esperance Plains, Warren	Northern Agricultural, Swan, South West, South Coast	Strategic taxonomic studies in families including Epacridaceae, Rafflesiaceae, Rhamnaceae and Dilleniaceae	75
Midwest, Wheatbelt, Swan, South Coast, South West, Warren	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Esperance Plains, Warren	Avon, Swan, South West, South Coast	Susceptibility of rare and endangered flora to <i>Phytophthora</i>	94
All DPaW Regions	All IBRA Regions	All NRM Regions	Systematics of the triggerplant genus <i>Stylidium</i>	83
All DPaW Regions	All IBRA Regions	All NRM Regions	Taxonomic resolution and description of new plant species, particularly Priority Flora from those areas subject to mining in Western Australia	87
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	84
All DPaW Regions	All IBRA Regions	All NRM Regions	Taxonomic studies in selected families, including Asteraceae, Celastraceae, Malvaceae, Proteaceae	78
All DPaW Regions	Geraldton Sandplains, Avon Wheatbelt, Coolgardie, Swan Coastal Plain, Mallee, Esperance Plains, Warren	Northern Agricultural, Avon, Swan, South West, South Coast	Taxonomic studies on native and naturalised plants of Western Australia arising from biological survey	76
All DPaW Regions	All IBRA Regions	All NRM Regions	Taxonomy of selected families including legumes, grasses and lilies	80
All DPaW Regions	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren	All NRM Regions	Taxonomy of undescribed taxa in the Ericaceae subfamily Styphelioideae, with an emphasis on those of conservation concern	74
Midwest, Wheatbelt, Swan, South Coast, Warren	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren	Northern Agricultural, Swan, South West, South Coast	Temperature thresholds for recruitment in south-west Western Australian flora	82
All DPaW Regions	All IBRA Regions	All NRM Regions	The Western Australian Herbarium's specimen database	71
All DPaW Regions	All IBRA Regions	All NRM Regions	The Western Australian Plant Census and Australian Plant Census	70
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	85

DPaW Region	IBRA/IMCRA	NRM Region	Project Title	Page
Midwest, Goldfields, Wheatbelt, Swan, South Coast, South West	Avon Wheatbelt, Jarrah Forest, Esperance Plains	Rangelands, Northern Agricultural, Avon, Swan, South West, South Coast	The population ecology of critically endangered flora	93
Midwest, Wheatbelt, South Coast, South West	Geraldton Sandplains, Avon Wheatbelt, Coolgardie, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren	Northern Agricultural, Avon, Swan, South West, South Coast	Translocation of critically endangered plants	91
Pilbara, Midwest, Goldfields	Pilbara, Little Sandy Desert, Gibson Desert, Gascoyne, Central Ranges, Yalgoo, Murchison, Great Victoria Desert, Nullarbor, Coolgardie	Rangelands	Understanding mulga	68
ECOSYSTEM SCIENCE				
Swan, South West	Jarrah Forest	Swan, South West	Aspects of dieback behaviour relevant to the formulation of jarrah silviculture guidelines	110
Warren	Jarrah Forest	South West	Burning for biodiversity: Walpole fine-grain mosaic burning trial	115
Goldfields, Wheatbelt, Warren	Avon Wheatbelt, Coolgardie, Mallee, Warren	Wheatbelt, Rangelands, South Coast	Climate-resilient vegetation of multi-use landscapes: exploiting genetic variability in widespread species	104
South West, Warren	Jarrah Forest, Warren	Swan, South West	Evaluation of key soil indicators of sustainability in Australian mediterranean forests (Indicators 4.1d, 4.1e)	121
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	112
			Fire behavior and fuel dynamics in coastal shrublands	101
Kimberley	Northern Kimberley	Rangelands	Fire regimes and biodiversity decline in the Kimberley test	111
Goldfields, Wheatbelt, South Coast	Yalgoo, Avon Wheatbelt, Coolgardie, Mallee	Wheatbelt, Rangelands	Fire regimes and impacts in transitional woodlands and shrublands	108
Pilbara, Midwest, Goldfields, Wheatbelt, South Coast, South West, Warren	Murchison, Geraldton Sandplains, Avon Wheatbelt, Coolgardie, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains	Wheatbelt, Rangelands, Northern Agricultural, South West, South Coast	Genetic analysis for the development of vegetation services and sustainable environmental management	124
Swan	Jarrah Forest	Swan, South West	Hydrological response to timber harvesting and associated silviculture in the intermediate rainfall zone of the northern jarrah forest	120

DPaW Region	IBRA/MCRA	NRM Region	Project Title	Page
South West, Warren	Jarrah Forest	Swan, South West	Identification of seed collection zones for rehabilitation	112
Swan	Jarrah Forest	Swan	Landscape and fire management interactions and their effects on distribution of invertebrate biodiversity	119
			Long term response of jarrah forest understorey and tree health to fire regimes	102
Warren	Warren	South West	Long-term stand dynamics of regrowth karri forest in relation to site productivity and climate	105
Midwest, Wheatbelt, South Coast	Geraldton Sandplains, Avon Wheatbelt, Esperance Plains	Wheatbelt, Northern Agricultural, South Coast	Management of environmental risk in perennial land use systems	116
Swan, South West, Warren	Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren	Swan, South West, South Coast	Management of invertebrate pests in forests of south-west Western Australia	106
Warren	Warren	South West, South Coast	Monitoring post-fire effects from the 2001 Nuyts wildfire	114
Swan, South West, Warren	Jarrah Forest, Warren	Swan, South West, South Coast	Monitoring stream biodiversity (KPI 20 of the Forest Management Plan)	113
Kimberley	Northern Kimberley	Rangelands	North Kimberley Landscape Conservation Initiative: monitoring and evaluation	102
Goldfields	Gascoyne, Murchison	Rangelands	Project Rangelands Restoration: developing sustainable management systems for the conservation of biodiversity at the landscape scale in rangelands of the Murchison and Gascoyne bioregions—managing fire and introduced predators	117
Wheatbelt, South Coast, Warren	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren	Wheatbelt, Northern Agricultural, Swan, South West, South Coast	Protecting the safe havens: will granite outcrop environments serve as refuges for flora threatened by climate change?	107
Warren	Jarrah Forest, Warren	South West	Responses of terrestrial vertebrates to timber harvesting in the jarrah forest	100
Warren	Warren	South West	Restoring natural riparian vegetation systems along the Warren and Donnelly Rivers	99
Midwest, Wheatbelt, Swan, South Coast, South West, Warren	Geraldton Sandplains, Avon Wheatbelt, Jarrah Forest, Mallee, Esperance Plains	Wheatbelt, Northern Agricultural, South West, South Coast	State Salinity Strategy wetland monitoring	121
Warren	Warren	South West	The effect of wildfire on forest fungi	123
Warren	Warren	South West,	The impact of wildfire in old growth forest of the Walpole-Nornalup National Park on	118

DPaW Region	IBRA/IMCRA	NRM Region	Project Title	Page
		South Coast	short-range endemic invertebrates and their forest floor communities	
Midwest, Wheatbelt, Swan, South Coast, South West	Jarrah Forest, Mallee, Warren	Northern Agricultural, South West, South Coast	Understanding the changing fire environment of south-west Western Australia	98
Warren	Warren	South West	<i>Armillaria</i> spread in karri	125
MARINE SCIENCE				
			Access and human use at Penguin Island and related implications for management of Marine Park assets and visitor risk	127
Pilbara	Pilbara, Ningaloo	Rangelands	Effects of the Gorgon Project dredging program on the marine biodiversity of the Montebello/Barrow Islands marine protected areas	135
			Improving the understanding of West Pilbara marine habitats and associated taxa: their connectivity and recovery potential following natural and human induced disturbance	128
Pilbara	Ningaloo	Rangelands	Interactive effects of fishing and climate change on coral reef fish populations	138
Kimberley, Pilbara	Northwest Shelf	Rangelands	North West Shelf Flatback Turtle Conservation Program strategic plan	132
Pilbara	Pilbara (Offshore), Pilbara (Nearshore)	Rangelands	Review, assess and summarise historical data relevant to the management of the proposed Dampier Archipelago Marine Park and Regnard Marine Management Area	131
Warren	WA South Coast	South Coast	Spatial and temporal patterns in benthic invertebrate communities of the Walpole and Nornalup Inlets Marine Park	137
Swan	Central West Coast	Swan	Spatial and temporal patterns in the structure of intertidal rocky platform communities of the Shoalwater Islands and Marmion marine parks	139
Midwest	Shark Bay	Rangelands	Spatial variation in the functional morphology of mangroves in the Shark Bay World Heritage Area	135
All DPaW Regions	All IBRA Regions, All IMCRA Regions	All NRM Regions	The Western Australian Marine Monitoring Program (WAMMP)	130
			The influence of macroalgal fields on coral reef fish	129
Kimberley, Pilbara	Oceanic Shoals, Bonaparte Gulf, Kimberley, Northwest Shelf, Cambridge-Bonaparte, Canning, King Sound, Eighty	Rangelands	WAMSI 2: Kimberley Marine Research Program	133

DPaW Region	IBRA/IMCRA	NRM Region	Project Title	Page
	Mile Beach			
ECOINFORMATICS				
All DPaW Regions	All IBRA Regions, All IMCRA Regions	All NRM Regions	Online GIS biodiversity mapping (NatureMap)	142
All DPaW Regions	All IBRA Regions, All IMCRA Regions	All NRM Regions	Plant species richness and endemism within the south-western Australian Floristic Region	143
All DPaW Regions	All IBRA Regions, All IMCRA Regions	All NRM Regions	Provision of authoritative names of Western Australian taxa	141

RESEARCH ACTIVITIES

BIOGEOGRAPHY

STEPHEN VAN LEEUWEN

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

South-Western Australia Transitional Transect (SWATT)

SPP 2013-003

Team members

R Meissner, N Gibson, S van Leeuwen, M Byrne, R Coppen, M Langley, Dr S Prober (CSIRO)

Context

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

Aims

- Define, describe and understand the floristics and vegetation communities on deep sand plains across the transect to provide a baseline for monitoring change and impacts of disturbance, e.g. fire.
- Identify sensitive, important or significant species and communities in the sand plain vegetation community and provide management recommendations.

Summary of progress and main findings

- Ten sites encompassing 160 quadrats have been established on the SWATT and soil samples for textural and chemical analysis have been collected. Systematic sampling of flowering plants and recording of a series of vegetation structural and life history attributes has been completed.
- Soil analysis has been completed, soil samples have been archived in CSIRO National Soil Archive in Canberra. Results from soil textural and chemical analyses have been provided to the Terrestrial Ecosystems Research Network's (TERN) ecological data storage facility - Ækos.
- Plant identifications have been completed.

Management Implications

A more detailed understanding of the beta-diversity patterns and vegetation structural attributes of the sandplains will enable:

- implications of large-scale development proposals on biodiversity values to be better appreciated;
- the amount of additional survey required to adequately assess large-scale development proposals to be determined;
- implications of current fire management practices on biodiversity values to be assessed;
- a more accurate assessment of the current reservation status of the sand plain vegetation types to be developed;
- better understanding of the conservation status of many species restricted to sand plain habitats.

Future directions (next 12 to 18 months)

- Commence a detailed statistical analysis of floristic patterning on sand plain vegetation communities along the SWATT, paying particular attention to compositional change and how such change is being influenced by edaphic attributes.
- Investigate changes in the distribution of life history classes along the transect and relate to environmental attributes.
- Through spatially explicit ordination approaches investigate patterns of beta diversity and complementarity in patterns observed with respect to those patterns previously identified for the Banded Iron Formation ranges of the Yilgarn.
- Seek additional resources to expand research activities along the SWATT to capture patterns of biodiversity amongst various faunal groups and across other vegetation types.

Western Australian flora surveys

SPP 2012-005

Team members

N Gibson, N Casson, G Keighery, R Meissner, M Langley, M Lyons, C McCormick, S van Leeuwen, A Markey, R Coppen

Context

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

Current projects include:

- AusPlots Rangeland survey sites as a baseline for long-term monitoring in collaboration with the Terrestrial Ecosystems Research Network (TERN). This AusPlots WA campaign has focused on the Coolgardie and Murchison Bioregions in the Great Western Woodlands.
- Flora survey of the Katjarra (Carnarvon Range) Indigenous Protected Area (IPA) in collaboration with the Birriliburu Native Title Claimants to aid future management. Survey campaign funded by Central Desert Native Title Services and undertaken in collaboration with Birriliburu Rangers and Bush Heritage Australia.
- Floristic survey and mapping of the halophyte-dominated communities of the Fortescue Marsh.
- Vegetation mapping data for the Great Western Woodlands and Indian Ocean Drive to inform natural resource management and land use planning.

Aims

- Establish AusPlots Rangeland survey sites using the TERN protocol in the Great Western Woodlands.
- Undertake a floristic survey of the Katjarra (Carnarvon Range) Indigenous Protected Area (IPA) to inform management.
- Undertake floristic survey and mapping of the halophyte dominated communities of the Fortescue Marsh.
- Compile vegetation mapping data for the Great Western Woodlands and Indian Ocean Drive to inform natural resource management and land use planning.

Summary of progress and main findings

- AusPlots in the 2013/14 campaign in the Great Western Woodlands with an additional three sites located within the Katjarra IPA.
- Undertaken a field trip to the Katjarra IPA where twenty permanent floristic plots were established and targeted surveys for species of interest were undertaken. Identification of the collections during the May 2014 field trip is continuing. A draft of the flora report for the Katjarra survey has been prepared.
- Plant identifications for vouchers collected during the first sampling session in 2013 were completed and progress reports prepared for both BHP Billiton Iron Ore and the Fortescue Metals Group. The new taxon *Samolus* sp. Fortescue Marsh (A. Markey & R. Coppen FM 9702) was formally named. A second field sampling session commenced in June 2013.
- The Vegetation Map Reconciliation project for the Great Western Woodlands was completed, uploaded onto NatureMap and successfully delivered to South Coast NRM.
- The Vegetation Map Reconciliation project for Indian Ocean Drive between Lancelin and Jurien was completed and successfully delivered to the WA Local Government Association and Department of Planning.

Management Implications

- The Katjarra IPA survey has more than doubled the number of known plant taxa from the area, and has identified a number of significant range extensions, new populations of Priority Flora and one possible new taxon. Data from this survey will inform future management of the IPA.
- Data from the Fortescue Marsh floristic survey and vegetation mapping project will provide documentation of the conservation values of the Marsh and input into ongoing management, land use planning and environmental approvals processes for this very important arid zone wetland.
- Data from AusPlots will ultimately be web-based and freely available, creating the opportunities for management to be informed by researchers who: i) interrogate vegetation structure, composition and metagenomics, and soil structure and metagenomics; ii) use the plots as ground-truth for remote sensing purposes; iii) potentially cross-correlate cover and/or 3D imagery with biomass/carbon cycling; and iv) revisit the sites to ground-truth change and outline vegetation dynamics.
- Data compiled via the Great Western Woodland and Indian Ocean Drive vegetation map reconciliation projects will primarily be used to inform land use planning and natural resource management activities. The maps provide information on vegetation values associated with land rezoning plans, fire management activities and impact assessment from resource development. The derived products also highlight the knowledge gaps associated with the coverage of existing vegetation mapping products for the two biological significant regions.

Future directions (next 12 to 18 months)

Further surveys will be undertaken as required and when resources become available. The development of collaborative arrangements to facilitate future surveys is underway and involves discussions with Traditional Owners, natural resource managers, resource developers and both government and private sector managers of land and biodiversity assets.

Western Australian terrestrial fauna surveys

SPP 2011-021

Team members

L Gibson, M Cowan, N Guthrie, N McKenzie, AH Burbidge

Context

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

Aims

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

Summary of progress and main findings

- Katjarra (Carnarvon Range) Indigenous Protected Area (IPA) biological survey of mammals and reptiles in March 2014 was the third survey in a partnership with the Birriliburu native title holders. Approximately 280 individuals were caught representing more than 60 fauna species. From the combined surveys 40 of the now 99 recorded species are new distributional records within this part of the Little Sandy Desert bioregion. Many of these species are significant range extensions. A supplementary survey in May 2014 focussed on documenting the bird fauna of the survey sites.
- Vertebrate Fauna Survey of Millstream Chichester National Park's NatureBank Envelopes-Narrina Gorge and Ashburton. This survey of two possible eco-tourism development sites was undertaken to ensure that development opportunities are not constrained by the presence of rare or threatened vertebrate fauna. Work was carried out with the support of staff from the Pilbara Region and also involved Yindjibarndi Rangers. A total of 110 species were identified, including two frogs, 35 reptiles, 54 birds and nine mammals, with two of these species of conservation significance. Six species were the first documented occurrences within the National Park.
- Surveys of Lacrosse Island, Buckle Head and a mainland site within the Berkeley subregion of the North Kimberley were conducted in May 2014. This campaign was a partnership between Science and Conservation Division, the Kimberley Region and Ballengarra Rangers, funded through the Kimberley Science and Conservation Strategy. These surveys resulted in the identification of nine non-volant mammals, more than 20 bats, 26 reptiles and eight frogs, along with the collection of over 300 tissue samples. Several of the mammal records are significant as they confirm the presence of species in areas where they were previously not known.

Management Implications

- The immediate aims of the individual projects vary depending on the needs of the funding source, but usually contribute to improved species distributional and ecological understanding, prioritisation of conservation actions by local managers, and/or the assessment of potential environmental impacts of land use proposals. Individual survey projects assist regional conservation and land managers to understand local biodiversity patterning and its underlying drivers, and permit the use of this information to assess environmental impacts, prioritise conservation actions, set biodiversity targets, establish baselines for monitoring and monitor

change. The combination of surveys enable improved understanding of species distributions and habitat requirements at a state level, thus contributing to bioregional analyses, reviews of species' conservation status and analyses of the relationships between species and broad-scale gradients and threats such as climate change.

Future directions (next 12 to 18 months)

Further surveys will be undertaken as required and when resources become available. The development of collaborative arrangements to facilitate future surveys is underway and involves discussions with Traditional Owners, natural resource managers, resource developers and both government and private sector managers of land and biodiversity assets. Future initiatives may include:

- Two surveys in the Great Victoria Desert region will provide biological information for two areas where such information is lacking.
- Survey of Champagny Island in collaboration with the Dambimangari Rangers and the Kimberley Region.

Western Australian wetland fauna surveys

SPP 2011-018

Team members

A Pinder, K Quinlan, Dr RJ Shiel (University of Adelaide)

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 umbrella project is designed to fill gaps within and between the regional surveys by providing aquatic invertebrate biodiversity data and analyses at finer scales. Past examples of such projects are surveys of wetlands in the Drummond, Warden and Bryde Natural Diversity Recovery Catchments, the Hutt River/Hutt Lagoon catchments and the mound springs near Three Springs. This project runs on an 'as-needed' basis.

Aims

- Provide understanding of aquatic biodiversity patterning at the scale of individual wetlands to wetland complexes and catchments 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.

Summary of progress and main findings

- Completed paper on aquatic invertebrate diversity and distributions in 25 wetlands along the Cervantes to Coolimba coastline.
- Surveyed for Western Swamp Tortoise food resources (invertebrate diversity and biomass) in several complexes of Swan Coastal Plain wetlands. Biomass data provided to Western Swamp Tortoise project. Biodiversity samples are being processed.
- Undertook opportunistic sampling of aquatic invertebrates in Goldfields wetlands following late summer rains in early 2014. These samples are being processed.

Management Implications

- Wetlands of the Cervantes to Coolimba region support a diverse array of aquatic invertebrates, but most of these are widespread within the south-west of the State. The composition of the aquatic invertebrate fauna is a function of the diversity of hydrological regimes, water chemistry and vegetation structure of the wetlands. While the fauna does not include a significant component adapted to groundwater or spring habitats, the springs provide a permanent over-summer refuge (and recolonisation source) for a significant proportion of the region's aquatic invertebrate fauna. The salt lakes support most of the known populations of the endemic brine

shrimp *Parartemia extracta* so this needs to be considered when assessing applications to expand gypsum mining in the region.

Future directions (next 12 to 18 months)

- Publish reports or papers on the aquatic invertebrate diversity and conservation significance of the Three Springs mound springs, and selected Goldfields wetlands.
- Analyse trends in invertebrate biomass from Swan Coastal Plain Wetlands as Western Swamp Tortoise food.
- Publish paper on invertebrate diversity in vegetated claypans of south-west WA.

Development of ethically acceptable techniques for invertebrate wet-pit trapping

SPP 2010-005

Team members

M Cowan, S van Leeuwen, N Guthrie, Dr T Oldfield (Consultant Vet), Dr D Harris (WA ChemCentre), Dr K Ho (WA ChemCentre), A/Prof B Mullins (Curtin University)

Context

Over the past 15 years the technique of invertebrate wet-pit trapping has become a standard practice in biological survey, biogeographic research and condition monitoring programs. Relatively small aperture pits with a preserving fluid are buried flush with the ground and left *in situ* for extended periods (several months) to sample terrestrial invertebrates. This has enabled an unprecedented insight into the temporal and spatial structuring of invertebrate communities - a highly significant but comparatively poorly understood component of the Western Australian biota.

However, a consequence of this sampling technique is the inadvertent capture of vertebrates, which creates an ethical issue. The combination of glycol and formalin used in these pits is likely to result in a distressing demise for vertebrates as they are able to swim and stay afloat in the solution for some time, and the chemical solution is likely to act as an irritant. Also, the quality of the subsequently preserved material is of limited use beyond initial species identifications.

Aims

- Establish wet-pit trapping chemistry that ensures rapid death to both target and non-target fauna with the least distress possible.
- Achieve a level of preservation in captured organisms suitable not only for species identification, but also for morphological and molecular taxonomic research.

Summary of progress and main findings

- Laboratory trials of ethanol/propylene glycol stability and evaporation rates have been concluded and a report from this work is in the final stages of preparation.
- Final field trials of comparisons of non-target capture rates between ethylene glycol and ethanol/propylene glycol have been completed at Dryandra State Forest. Analysis of the captures from this work is ongoing.
- A modified wet pit design that aims to minimise evaporative loss of a ethanol/propylene glycol solution has been trialled in the field at Dryandra State Forest and on the Swan Coastal Plain.
- Regression calculations of evaporation rates in the modified traps under field conditions in warm to hot conditions are promising indicating that longevity of the solution should be upwards of 40 days, depending on concentrations and volumes.
- A sample of vertebrate and invertebrate captures from the field trial are still to be assessed for the quality of morphological and molecular preservation.

Management Implications

- Identification of an acceptable chemical solution will enable continued use of invertebrate wet-pitfall sampling, which is essential for a number of broad-scale biodiversity monitoring

programs underway within the Department of Parks and Wildlife, as well as for environmental impact assessment and conservation planning through regional- and local-scale biological surveys and condition monitoring programs.

Future directions (next 12 to 18 months)

- Verify that both vertebrate and invertebrate material is suitable for morphological and molecular studies after immersion in ethanol/propylene glycol preserving solution.
- Assess quality of molecular fixation from final field trial.
- Discuss implications of all trials and findings with the Department's Animal Ethics Committee.
- If methods are approved by the Animal Ethics Committee, assist Regions involved in invertebrate wet pit sampling to implement new methods where appropriate.
- Complete report on all results and findings, publish outcome in a peer-reviewed journal.

Biological survey of the Ravensthorpe Range

SPP 2007-006

Team members

N Gibson

Context

The biodiversity values of the Ravensthorpe Range, an area highly prospective for mineral exploration and mining, are poorly documented and understood. The range is known for possessing high numbers of both threatened and/or locally endemic plant species and distinctive and/or threatened ecological communities. Recent and historical resource developments on the range and in the near vicinity have had significant issues with threatened flora and vegetation management. A botanical survey of the Ravensthorpe Range is being undertaken to acquire additional knowledge on the floristics of the range, provide a comprehensive dataset from site-based plots on the distribution of species and floristic communities across the range, and to investigate the relationship between the floristic communities and mapped vegetation units.

Aims

Identify and quantify the botanical diversity of the Ravensthorpe Range.

Summary of progress and main findings

- Draft paper on Ravensthorpe Range floristic communities and vegetation map prepared.

Management Implications

This survey will provide a regional context for the assessment of impacts from proposed resource developments and land use planning decisions on the conservation values of flora and vegetation of the Ravensthorpe Range.

Future directions (next 12 to 18 months)

Further effort will aim to finalise and publish a paper on the correlation between floristic communities and vegetation mapping for the Range. Consideration will also be given to obtaining a more appropriate climatic surface for the range which can then be employed to model species and community distributions.

Kimberley islands biological survey

SPP 2007-001

Team members

L Gibson, M Cowan, M Lyons, R Palmer, G Keighery, N McKenzie, D Pearson

Context

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

Aims

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

Summary of progress and main findings

- Publication of ten scientific papers (background/logistics, non-volant mammals, land snails, bats, birds, frogs, Traditional Owner perspective, reptiles, plants and synthesis) in a dedicated edition of the Records of the Western Australian Museum (WAM), Supplement 81 (available online via WAM website).
- Presentations at various forums regarding Kimberley island biodiversity including the Island Arks Symposium III.

Management Implications

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

Future directions (next 12 to 18 months)

- Production and publication of the printed volume.
- All data made available via NatureMap.
- Continue knowledge transfer activities, including presentations to community groups.

Pilbara regional biological survey

SPP 2004-002

Team members

N McKenzie, N Guthrie, AH Burbidge, S van Leeuwen, M Lyons, A Pinder, M Langley, L Gibson, N Gibson

Context

The Pilbara is an economically important region in Western Australia, with major and expanding mineral extraction and pastoral industries. Effective biodiversity conservation is required to minimise the adverse impacts of these activities and other threatening processes, such as altered fire regimes

on the Pilbara's diverse flora and fauna. This survey addresses problems of incomplete knowledge of biodiversity (composition, patterns, status and trend) for nature conservation planning, including conservation reserve system gaps and weed invasions. Sampling includes reptiles, frogs, small ground mammals, bats, birds, arachnids, beetles, ants and aquatic invertebrates including stygofauna, wetland and terrestrial flora and soils, to overcome low cross-taxon congruence in biodiversity models.

Aims

- Provide data on the distribution of the biota and a regional perspective on biodiversity and nature conservation priorities across the Pilbara.
- Identify gradients in community composition and the environmental factors related to these gradients.

Summary of progress and main findings

- The stygofauna paper, now published online, is the 15th of the 18 refereed papers that comprise the Pilbara survey report to date.
- The riparian flora paper is ready to be submitted for review.
- The wetland aquatic flora paper is in preparation.
- Terrestrial flora identifications are complete, and the data matrix is being error-checked.
- Modelling of the now compiled terrestrial zoology and aquatic biodiversity data-sets for conservation gap analyses has been completed and the paper is in manuscript pending provision of final values for some tables and final General Dissimilarity Modelling maps by the CSIRO.
- The survey team are providing data, publications, presentations and advice on the survey's findings to a range of local, regional and national stakeholders, including the pastoral and mining industry, Departmental Pilbara staff, EPA/OEPA, Commonwealth agencies as well as the wider conservation, science and environmental consultancy communities.

Management Implications

- Survey information forms the basis for systematic regional nature conservation planning for the development of a conservation reserve system, and greater knowledge of the distribution and conservation status of species (indigenous and weeds) and ecological communities.
- The survey has provided an explicit, quantitative understanding of patterns in biodiversity across the Pilbara region as a regional context for environmental protection and land use planning. Voucher collections and plot based data sets that have been curated, identified and lodged in state natural history collections and data portals (NatureMap) provide baseline information for long-term ecological monitoring of the region.

Future directions (next 12 to 18 months)

- Publish the reptile and frog, historical bird, stygofauna, aquatic flora, riparian flora and conservation gap analysis papers as hardcover volume 'Part 2'.
- Complete and analyse the terrestrial flora matrix then draft and submit the flora paper for publication.
- Undertake communication activities on survey findings and outputs.
- Upload dataset to NatureMap under a Pilbara Biological Survey theme.

Oligochaete taxonomy

SPP 1998-008

Team members

A Pinder, K Quinlan

Context

Benthic invertebrates play a major role in aquatic sediment processes, as they do in terrestrial soils, including organic-matter processing, sediment turnover, particle sorting, aeration of sediments and structuring of sediment microbial communities. Aquatic oligochaetes (earthworms) are important members of these marine and freshwater benthic communities but are not well described in Western Australia. Aquatic oligochaetes also show considerable regional endemism in subterranean and epigeal aquatic systems and the ability to identify these species therefore contributes to better understanding of biogeographic patterning of aquatic fauna.

Aims

Describe the Western Australian aquatic oligochaete fauna, including descriptions of new species and production of keys to their identification.

Summary of progress and main findings

- Published the proceedings of the 12th International Symposium on Aquatic Oligochaeta, held in Fremantle, Western Australia, September 2012 available at the following url: (<http://www.mapress.com/zoosymposia/content/2014/v9/index.htm>).
- Published a description of a new species of aquatic oligochaete from Campbell Island in the subantarctic.

Management Implications

Aquatic oligochaetes show very high levels of regional endemism and habitat specificity within Western Australia, and knowledge of this contributes to conservation planning, including assessment of stygofauna communities in environmental impact assessment.

Future directions (next 12 to 18 months)

- Continue to describe new species of aquatic oligochaetes and identify specimens for the department's aquatic ecology projects.

ANIMAL SCIENCE

KEITH MORRIS

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

Cat Eradication on Dirk Hartog Island

SPP 2014-003

Team members

D Algar

Context

On Dirk Hartog Island, the largest island off the Western Australian coast, 10 of the 13 species of native terrestrial mammals once present are now locally extinct most likely due to predation by cats. The island was established as a National Park in November 2009, which now provides the opportunity to reconstruct the native mammal fauna. Dirk Hartog Island could potentially support one of the most diverse mammal assemblages in Australia and contribute significantly to the long-term conservation of several threatened species. Eradication of feral cats would be a necessary precursor to any mammal reintroductions. The objective of this project is to develop and implement a successful eradication campaign for feral cats on the island.

Aims

The aims of this project are to facilitate native fauna reintroductions to Dirk Hartog Island through researching feral cat behaviour and susceptibility to baiting programs, implementing a cat eradication program, and developing effective cat monitoring protocols that will allow success of eradication programs to be assessed.

Summary of progress and main findings

- Construction of temporary accommodation at the southern campsite (Herald Bay), including accommodation and equipment storage, has been completed.
- Monitoring track access in the southern section and installation of camera traps has been completed.
- The first baiting operation was undertaken late May 2014.
- Conducted pre-bait monitoring survey, baiting program, and post-bait monitoring survey at the southern site.
- Barrier fence construction has commenced and is due to be completed mid-August.

Management Implications

The biodiversity outcome from this project will be a measurable decline in the cat population on Dirk Hartog Island, eventually to zero when eradication is confirmed. This is essential before fauna reconstruction activities can commence. Cat eradication will also assist the conservation of the extant fauna, including three threatened taxa. There will be global interest in the outcome of this project and the techniques used. Knowledge and technology transfer to other agencies contemplating cat eradications on islands will be through presentations and publication of manuscripts in scientific journals.

Future directions (next 12 to 18 months)

- Undertake monthly monitoring and trapping programs at the southern site.

- Complete construction of cat barrier fence, and infrastructure at the northern site campsite (Sandy Bay).
- Install monitoring track access in the northern section and installation of camera traps.
- Conduct baiting program at the northern site.

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

SPP 2013-005

Team members

N Thomas, M Cowan, B MacMahon

Context

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

Aims

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

Summary of progress and main findings

- Completed two camera trap trials in Dryandra Woodland and one in Tutanning. Results indicate that camera trapping provides consistent, reliable and comparable species accumulation and detection rates.
- Tutanning camera trap trial confirmed that woylies are no longer at detectable levels in the reserve.
- Further analysis of bait versus un-baited trial data indicates decline in detection rates at baited cameras over time.
- Completed analysis of species relative abundance from cameras deployed during a known removal event (translocation of woylies to Perup), which showed the method is sensitive enough to detect changes in relative abundance of a species.
- Quantified required effort to detect all species (mammals) within Dryandra, which can be extrapolated to other reserves.
- Provided advice and methodologies to other sections within Parks and Wildlife, and other Tertiary institutions and NGO's.

Management Implications

- Camera traps appear to be an effective tool in detecting a suite of species currently not adequately monitored by the Western Shield monitoring program. Their use should be considered in the Western Shield monitoring program, either to complement the trapping program, or as a separate fauna monitoring tool.
- Recommend that the Reconyx HC600 series cameras are adopted as the minimum standard of camera to be used across the department, but preference should be for the PC900 camera due to its reliability and greater functionality, including its operation over a wider temperature range.
- The open source Access database, Camera Base 1.6 (<http://www.atrium-biodiversity.org/tools/camerabase/>), be adopted (with some minor modifications) as the standard method of capturing and storing camera trap data. Camera Base 1.6 to be used in conjunction with an image processing software such as Faststone Image Viewer.
- A standardised mounting method that is cohesive and repeatable between sites should be adopted for monitoring purposes.
- Camera traps consistently detect species that are not currently censused using most other standard detection/monitoring methods, and provide an effective mounting method for these species.

Future directions (next 12 to 18 months)

- Develop a number of standard Access queries to better analyse outputs from Camera Base, and provide this to Regional staff using Camera Base.
- Validate camera traps against other traditional methods of fauna monitoring, such as cage trapping or sand plots.
- Investigate methods to use camera traps to qualitatively and quantitatively monitor invasive species.
- Investigate the sensitivity of camera-trap data to detect changes in relative abundance and occupancy of targeted species over time and season.

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

SPP 2013-001

Team members

K Morris, L Gibson, C Lohr

Context

The goal of this project is to prioritise island management actions such that we maximise the number of achievable conservation outcomes for island biodiversity in the face of threats from invasive species. Western Australia has over 3700 islands, many of which are essential for the survival of threatened species and provide critical breeding sites for seabirds and sea turtles. Many islands are also popular sites for recreation, and contain culturally significant sites. Invasive species are the single biggest cause of loss of native species from islands. The increased use of islands by the public for recreation, and oil, gas and mining industries, means an increased likelihood that invasive species will colonise pristine islands. This project will develop a decision support tool for day-to-day use in making accountable and cost-effective decisions on the management of islands to promote the persistence of native species. The decision support tool will be developed in collaboration with researchers from James Cook University, Queensland. The project will initially focus on the 600+ islands along the Pilbara coast.

Aims

- Develop a single comprehensive database on Pilbara island characteristics, fauna and flora values, and threats.

- Develop an operational decision support tool for day-to-day use in making accountable and cost-effective decisions about where to spend limited funding on management of islands to promote the persistence of native species.
- Enable accountable and cost effective decisions that aid the conservation of Western Australia's islands and native species.

Summary of progress and main findings

- Two meetings with Pilbara island managers.
- Workshop with Pilbara island experts in preparation for the first elicitation workshop.
- Presentation at Island Arks Symposium III.
- Paper in preparation addressing changes in vegetation cover before, during and after rodent eradications on the Montebello Islands.
- Pilbara island database populated with all available published and unpublished information and is estimated to be 90% complete.

Management Implications

- The decision support tool will result in more cost effective biosecurity management of valuable island conservation reserves.
- A single comprehensive and easily accessible database on Pilbara island characteristics, biodiversity values and threats will facilitate island planning and management operations.

Future directions (next 12 to 18 months)

- Expert elicitation workshops to populate data tables.
- Formulate model and sub-model components.
- Workshops with island managers to review model parameters and formulation.
- Test the decision support tool and train managers in application of the model.
- Seek opportunities to expand islands database to include Kimberley islands.

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

SPP 2012-035

Team members

M Dziminski, F Carpenter, K Morris

Context

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

Aims

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

Summary of progress and main findings

- Population viability analysis on how much land area is required to create reserves for bilbies completed and being submitted for publication.
- NatureMap theme for Bilby and other Pilbara threatened species completed and published online: <http://naturemap.dec.wa.gov.au/Query.aspx?querytype=content&content=PILBFAUNA>.
- User contributable online database system completed and published online: <http://dpaw.gaiaresources.com.au/bdrs-core/home.htm>.
- 243 records of bilbies entered in the database. Search of all published and unpublished literature was completed. Interviews with landholders and managers are ongoing to add data to the database.
- Poster and Information Sheets completed and published.
- Habitat modelling using above data currently being performed in collaboration with other Parks and Wildlife scientists.
- 369 sites in the Pilbara physically surveyed, resulting in 86 positive records of bilby presence or activity.
- External collaboration being developed for the use of remotely piloted aircraft for surveys for bilbies.
- Fine scale population monitoring technique using scats collected quantitatively to genotype individuals has been developed and is being refined.
- Three populations are being monitored using the above technique, in collaboration with stakeholders, with five more populations to be included in the near future.

Management Implications

This research will develop consistent and refined survey and monitoring techniques for bilbies in the Pilbara Bioregion, with the potential for broader state and national applications. The data and records gathered will improve understanding of bilbies in the Pilbara, and allow for habitat modelling and predictions of bilby distribution. This in turn will inform future management of bilby populations and assist in the assessment of mining and development proposals.

Future directions (next 12 to 18 months)

- Continue to develop collaboration on using remotely piloted aircraft to survey for bilbies.
- Model bilby habitat in collaboration with other Parks and Wildlife scientists.
- Include more populations to the long-term monitoring program, developing more collaborations with stakeholders to monitor bilbies in their tenure.

Genetic assessment for conservation of rare and threatened fauna

SPP 2012-034

Team members

K Ottewell, M Byrne, K Morris, D Coates

Context

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

Aims

- Resolve taxonomic boundaries of Western Australian bandicoots (*Isoodon* sp.), particularly *I. auratus* and *I. obesulus* and their subspecies, to determine appropriate conservation rankings.

- Assess genetic diversity and effective population size of source and translocated populations of golden bandicoot (*I. auratus*) and perform population viability analysis to predict the long-term trajectory of translocated populations.
- In collaboration with Brian Chambers (UWA) investigate the role of fauna underpasses in providing connectivity between quenda (*I. obesulus* ssp. *fusciventer*) populations impacted by main road construction.

Summary of progress and main findings

- Genetic and statistical analysis of golden bandicoot translocations has been completed and published in the journal *Biological Conservation*.
- Tissue samples of *I. obesulus*, *I. auratus*, *I. macrourus* and their subspecies have been sourced for taxonomic analysis and mitochondrial and nuclear sequencing of these is nearing completion. Data will be incorporated into a broader phylogeny of the genus *Isoodon* (including eastern states species) in collaboration with Steve Cooper of the SA Museum. Preliminary analysis suggests revision of *I. obesulus* sub-species designations will be required.
- DNA analysis of quenda populations has been completed and population genetic and population viability analyses are currently being undertaken to investigate gene flow rates between populations connected by fauna underpasses.

Management Implications

- Population viability analysis in conjunction with genetic data provides a means of determining the effective population sizes required to maintain translocated populations of animals. Results show the initial translocation of golden bandicoots to Lorna Glen, Hermite and Doole Islands has successfully conserved genetic diversity but in populations with less than ~1000 animals genetic diversity will erode with time and periodic supplementation will be required. Expansion of the Lorna Glen enclosure would enable a larger population to be maintained and will benefit the long-term viability of the translocated bandicoot population.
- Resolution of taxonomic boundaries between *I. obesulus* and *I. auratus* and their broader relationships with eastern states bandicoots should enable revision of current threatened species status at state and commonwealth levels.
- Genetic and population viability analysis will be used to determine whether fauna underpasses are suitable for maintaining population connectivity in the short and long-term for quenda, and potentially other wildlife populations, affected by road barriers.

Future directions (next 12 to 18 months)

- Complete sequencing of mitochondrial and nuclear markers for taxonomic analysis of *Isoodon* spp.
- Prepare manuscript on the taxonomy and phylogeny of *I. auratus*, *I. obesulus* and *I. macrourus*, and contribute to manuscript on the broader phylogeny of *Isoodon*. Investigate use of coalescent models to infer the evolutionary history of the genus.
- Complete genetic and population viability analysis of quenda populations and prepare manuscript.

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

SPP 2012-033

Team members

K Ottewell, M Byrne, K Morris, D Coates

Context

Human-mediated landscape disturbance can affect the amount of genetic diversity present in populations of threatened species and their distribution across the landscape. One challenge facing conservation managers is understanding how management tools can be used to protect and facilitate genetic patterns and processes. For example, reserve design principles (comprehensiveness,

adequacy, representativeness; single large or several small) can be just as well applied to conserve genetic diversity as species diversity.

Aims

- Use genetic approaches to investigate patterns of contemporary and historical diversity in target species to understand how best to conserve the processes that generate these patterns.
- Determine genetic diversity and gene flow amongst quenda (*Isoodon obesulus* ssp. *fusciventer*) populations in fragmented and continuous populations in the Perth region, in reserves of varying size and connectivity.
- Identify habitat features that are associated with high genetic diversity and gene flow in quenda populations using GIS and habitat modelling, and how well these features are captured in the reserve system.
- Assess the genetic diversity and genetic structure of target species in the Pilbara and how this relates to climate and environmental features (soils, landforms, etc.), and is captured in the current reserve system.

Summary of progress and main findings

- Quenda tissue samples have been sourced from Parks and Wildlife, UWA, Murdoch University and environmental consultants that cover the Swan coastal plain and Perth Hills. DNA extraction and genotyping of quenda samples is almost complete.
- Pilbara mammal species have been selected for study and tissue samples have been sourced for several species. Microsatellite markers have been trialled in one species.

Management Implications

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

Future directions (next 12 to 18 months)

- Analyse genetic diversity and genetic differentiation between quenda populations and correlate this information with habitat data and species distribution models developed by Swan Coastal District.
- Determine mitochondrial and nuclear DNA sequence markers that are variable in Pilbara target species and complete sequence analysis.
- Develop niche-based species distribution models for Pilbara mammal species and correlate with genetic data.

Barrow Island Threatened and Priority fauna species translocation program

SPP 2012-025

Team members

K Morris, AH Burbidge, N Hamilton, N Thomas

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 WA 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 was the threatened and priority fauna translocation program that provides for the translocation of selected Barrow Island fauna species to other secure island and mainland sites. This will assist in improving the conservation status of these species, and also allow the reconstruction of the fauna in some areas. It was also an opportunity to examine the factors affecting translocation

success, and improve these where necessary. Targetted species are the golden bandicoot, brushtail possum, spectacled hare-wallaby, boodie, water rat, black and white fairy-wren, and spinifexbird.

Aims

- Successfully translocate selected mammal and bird species from Barrow Island to other secure island and mainland sites.
- Reconstruct the fauna in areas where these species have become locally extinct.
- Ensure ongoing appropriate management at the translocation sites, particularly introduced predators.
- Develop and refine protocols for fauna translocation and monitoring.

Summary of progress and main findings

- Monitored translocated species on the Montebello Islands, Doole Island and Lorna Glen. All translocated species at these sites have established and increased in abundance.
- No further translocations have occurred since 2012 due to lack of sites where feral cats and foxes are adequately under control.
- Taxonomic work on the water rat has shown that the Barrow Island form is sufficiently different from the south-west form to warrant subspecific status. This has implications for sourcing founder water rats for the proposed reintroduction to the Montebello Islands.
- Draft Barrow Island fauna translocation strategy developed.
- Draft business case for an expanded fenced enclosure at Lorna Glen prepared.
- Annual report on progress provided to Chevron.
- Project advisory group established.

Management Implications

Arid zone rangelands fauna reconstruction and conservation techniques developed by this project will have broad state and national application. The outcomes of the project will contribute to the management of Parks and Wildlife rangeland properties and provide guidance for future fauna reconstruction, e.g. Dirk Hartog Island. It will also contribute to an improvement in the conservation status of several threatened fauna taxa.

Future directions (next 12 to 18 months)

- Research into effectiveness of feral cat baiting at Cape Range to be undertaken in August 2014 so that an integrated fox/cat baiting regime can be developed for more effective reduction in fox and feral cat abundances. This will contribute significantly to this site becoming another fauna reconstruction site.
- Ongoing monitoring of the translocated mammals and birds at all the release sites. As part of this, a spectacled hare-wallaby monitoring program on Hermite Island using remote cameras will be developed.
- Barrow Island fauna translocation strategy to be finalised.
- Continue to plan for an expanded fenced enclosure at Lorna Glen in the context of an Indigenous Protected Area agreement with traditional owners.

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

SPP 2012-024

Team members

C Sims, K Morris, T Chapman, N Burrows, K Rayner

Context

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

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

The first of the mammal reintroductions commenced in August 2007 with the release of bilby (*Macrotis lagotis*) and wayurta (*Trichosurus vulpecula*). Another nine species of mammal are proposed for reintroduction over the next ten years. Between 2010–2012, mala, Shark Bay mice, boodies and golden bandicoot were translocated into an 1100 ha introduced predator proof fenced enclosure.

Aims

- Reintroduce 11 native mammal species to Lorna Glen by 2020, to improve the conservation status of these species.
- Re-establish ecosystem processes and improve the condition of a rangeland conservation reserve.
- Develop and refine protocols for fauna translocation and monitoring.
- Study the role of digging and burrowing fauna in rangeland restoration.

Summary of progress and main findings

- Monitoring of mulgara populations inside and outside the enclosure.
- Ongoing monitoring of bilbies and possums outside the enclosure.
- Ongoing, biennial monitoring of boodies and bandicoots inside the enclosure.
- Planning for the release of 100 golden bandicoots outside the fenced enclosure undertaken, taking into account the lessons learned from previous releases. The first adult golden bandicoot was trapped outside the fenced enclosure, most likely as a result of young, small animals moving through the fence.
- Effects of bilby, boodie and varanid digging activity on soils and plants examined. A study of relic bilby burrows found they could potentially provide more suitable habitats for the establishment and productivity of other species by moderating microclimates, accumulating nutrients and soil moisture, and ameliorating the potentially detrimental effects of bio-available aluminium.
- Eradicat baiting in 2013 reduced cat abundance by 60-70%.
- In 2014, 14 feral cats and 18 dingoes were fitted with satellite collars and their survivorship and movements will be monitored before, during and after the planned feral cat baiting.
- Business Plan prepared for the expansion of the fenced enclosure.

Management Implications

- Fauna reconstruction and monitoring techniques for arid zone rangelands developed by this project will have broad state and national application for the conservation of threatened fauna.
- The outcomes of the project will contribute to the management of Parks and Wildlife's rangeland properties and provide guidance for future fauna reconstruction, e.g. Dirk Hartog

Island. It will also demonstrate effective partnership models with traditional owners and facilitate collaborative management with traditional owners.

Future directions (next 12 to 18 months)

- Finalise a 10-year fauna translocation plan.
- Ongoing monitoring of bilbies and possums outside the enclosure, and of bandicoots, boodies, mala and Shark Bay mice inside the enclosure.
- Commence monitoring mulgara at Earraheedy (no cat control) for comparison with Lorna Glen.
- Undertake release of golden bandicoots outside the fenced enclosure subject to adequate feral cat control, and monitor survivorship.
- Develop strategies for releases of boodies and bandicoots outside the enclosure in the presence of low densities of feral cats.
- Investigate the influence of reintroduced mammals on soils and plants and their potential to facilitate restoration.

Conservation of south coast threatened birds

SPP 2012-022

Team members

AH Burbidge

Context

Identifying the conservation requirements of threatened south coast birds such as the Critically Endangered western ground parrot, the Vulnerable western bristlebird and the western subspecies of the western whipbird will aid *in situ* management of these taxa. Understanding responses to fire, biological and behavioural characteristics, such as vulnerability to predation, and nesting site requirements are essential knowledge for the conservation of these Western Australian endemics. This work is carried out in close collaboration with the South Coast Threatened Birds Recovery Team and regional staff, so as to optimise the value of this research for management decisions.

Aims

- Develop an understanding of the biological and ecological factors that limit the distribution and numbers of western ground parrots and western bristlebirds, including interactions with predators, habitat requirements and response to fire.
- Increase the survival chances of the western ground parrot, western bristlebird and western whipbird and increase their total population size through creation of management prescriptions that will benefit all threatened south coast animals.

Summary of progress and main findings

- Continued integrated predator management on the south coast in an adaptive management framework, including monitoring ground parrots in Fitzgerald River National Park and before and after baiting for cats in Cape Arid National Park. The monitoring protocols are being refined through use of audio recordings.
- Assisted in revision of fire management guidelines for the western ground parrot.
- Published preliminary results of genetic analysis of western whipbird phylogeny; outcomes being incorporated into formal conservation status listing.
- In collaboration with South Coast Region, progressed a captive management program for western ground parrots with development of protocols for captive breeding in collaboration with Perth Zoo.
- In collaboration with South Coast Region, provided synthesis of fire management procedures and outcomes for threatened birds on the south coast.

Management Implications

Knowledge of the biology and responses to threats of these bird species provides a basis for decision making and management actions for their recovery, especially with respect to of introduced predators and fire, in important conservation reserves on the south coast.

Future directions (next 12 to 18 months)

- Finalise writing up of data on response to fire by bristlebirds and write up data on morphometrics of the western ground parrot.
- Implement further field-scale feral cat control (with monitoring) in key ground parrot habitat (with South Coast Region).
- Oversee movement of the captive ground parrots to a new facility outside the department for future management of these birds, and use genetic relatedness to develop protocols for captive breeding program.
- Continue work on genetic relatedness of populations of whipbirds, to provide a whole of taxon overview of taxonomic and conservation status.

Ecology and management of the northern quoll in the Pilbara

SPP 2011-005

Team members

J Dunlop, J Lees

Context

The northern quoll *Dasyurus hallucatus* is listed as an threatened species under the federal *Environment Protection and Biodiversity Conservation Act 1999*. Mining offset provisions are being used to gain a better understanding of quoll distribution, ecology, demographics and management requirements in the Pilbara. There are two major components of the project: regional monitoring and disturbance area monitoring. Regional survey and monitoring of Pilbara northern quoll populations over 10+ years will provide a regional context for understanding population dynamics. Monitoring northern quoll populations at disused mine sites and quarries over a three- to four-year time frame will provide information related to impacts, such as loss of known or potential habitat critical to the survival of the species, loss of known or potential foraging/dispersal habitat, and introduction of barriers restricting dispersal opportunities and genetic flow.

Aims

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

Summary of progress and main findings

- Monitoring of quoll use of BHP quarry sites was completed in November 2013 and a final report prepared.
- Consultation with landholders to gather anecdotal and historical records of northern quoll distribution was commenced in late 2011 and continues.
- Distributional (presence / absence) study using motion sensor cameras was commenced in late 2011 and continues with more than 60 sites now surveyed. This includes habitat assessment and the data will be used for habitat modelling.
- Eight sites have been identified through camera surveys and are considered to have suitable quoll populations for inclusion in the long-term regional monitoring program.

- Trapping at the regional monitoring sites commenced and will continue for the next 8-10 years.
- The northern quoll research plan and monitoring protocols were modified following a workshop involving consultants and mining companies.
- The Pilbara Threatened Species portal was established in NatureMap allowing the recording of quoll records made by consultants and members of the public.

Management Implications

Improved understanding of northern quoll ecology and distribution in the Pilbara will allow appropriate management of northern quoll populations in and around mining sites and other developments. The long-term monitoring program will allow an assessment of natural fluctuations in quoll abundances and demographics for comparison with those at mining sites.

Future directions (next 12 to 18 months)

- Motion sensor cameras will be deployed at more sites (up to 40 more) to record presence/absence data and patterns of distribution across the Pilbara region. These sites include mining leases.
- Consultation with landholders to gather anecdotal and historical records of northern quoll distribution will continue.
- Publication of proceedings of the northern quoll workshop.

Conservation of the graceful sun-moth

SPP 2010-006

Team members

M Williams, C Bishop, A Williams

Context

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

Aims

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

Summary of progress and main findings

- Completed surveys and monitoring of graceful sun-moth populations.
- Ongoing maintenance of the department's Lepidopteran collection.

Management Implications

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

Future directions (next 12 to 18 months)

- Maintenance of sun-moth dry collection.
- Further examination of hybrid populations between the coastal graceful sun-moth (*Synemon gratiosa*) and inland claret sun-moth (*Synemon jcaria*).
- Publication of habitat model and genetic results.

Identifying the cause(s) of the recent declines of woylies in south-west Western Australia

SPP 2007-002

Team members

A Wayne, C Ward, C Vellios, M Maxwell

Context

The woylie (*Bettongia penicillata*) has declined by about 90% since 2001. Population declines have been rapid (<95% per annum), substantial (>90% lost) and have particularly impacted the largest and most important populations. Most of the remaining unaffected populations are small, isolated and inherently vulnerable. The woylie has been upgraded to Critically Endangered as a result.

Aims

- Determine the causal factor(s) responsible for the recent woylie declines in the Upper Warren Region of south-western Australia.
- Identify the management required to ameliorate these declines.
- Develop adequate mammal monitoring protocols that will enable future changes in population abundances to be quantified and explained.

Summary of progress and main findings

- The CFOC and NRM funded aspects of the project were completed in late 2013. Analysis and interpretation of data collected during these programs is ongoing. An ARC linkage project 'The Ecology of Parasite Transmission in Fauna Translocations' commenced in 2013 and Parks and Wildlife is an industry partner in this, contributing to the project design and providing assistance in the field. A WWF funded project also commenced in 2013, on a disease outbreak investigation for the woylie and a national workshop was convened in March 2014 in Perth to prepare a case definition, construct a differential diagnosis, identify the risk factors for cases and develop a tentative diagnosis. Work is ongoing in providing the data and analysis to complete these stages of the outbreak investigation for the purposes of finalising a scientific paper for submission in 2015. In 2013/14 FERT has supported the Wheatbelt district with sourcing 36 woylies from Dryandra to translocate into the Perup Sanctuary in July 2013 and continued to assist Donnelly District in the management and monitoring of the woylie insurance population in the Perup Sanctuary, including participating in the translocation of 192 woylies from the Sanctuary in June 2014 to two sites in the Greater Kingston area. Pre- and post-translocation monitoring of the destination sites has been done as part of the ARC funded project and will continue throughout 2014 and 2015.
- Ongoing monitoring indicates that woylie numbers have remained low and approximately stable at a regional level since 2008. Some sites display early signs of some recovery while others remain low or continue to decline.
- Woylie declines have been mortality-driven, principally due to the predation (particularly by cats) of individuals that may have become increasingly vulnerable due to disease.

- Woylies in the Perup Sanctuary have rapidly increased from their founder size of 41 in December 2010 to around 600 in April 2014. Thirty six woylies from Dryandra and five offspring from the remaining Tutanning individuals (now in captivity) have been introduced to Perup Sanctuary to increase the genetic diversity. Three woylie translocations of 87-91 individuals each have been completed from Perup Sanctuary to sites in Upper Warren where additional predator control has been applied.
- Collaborative disease investigations continue, particularly into the key associations with the declines.
- A Disease Outbreak Investigation is underway in collaboration with James Cook University and World Wildlife Fund, including a national workshop held in March 2014.
- Five species have now declined in succession over a 10 year period in the Upper Warren region (dunnart, wambenger, quenda, ngwayir and woylie), to similar extents (>90%), at similar rates and with no signs of significant or sustained recovery. Chuditch and koomal have more recently increased in the region.
- Several papers have been recently published in scientific journals and a comprehensive progress report was completed in October 2013.

Management Implications

- Insurance populations to conserve the remaining genetic diversity of the woylie remains a priority. Continued loss of genetic diversity due to important woylie populations remaining small or becoming extinct will compromise the recovery prospects and conservation of the species.
- More effective control of feral cats and foxes is critical for sustaining and facilitating the recovery of important woylie populations. Improved control and monitoring of introduced predators is therefore very important.
- Wildlife disease may contribute to woylie declines by making animals more vulnerable to predation. Resolution of the role of disease in the declines will directly inform woylie recovery strategies and management.
- The serial decline of multiple species of marsupial in the Upper Warren region is of serious concern requiring action, especially given the high conservation value of the area and of the populations it supports.

Future directions (next 12 to 18 months)

- This project is now complete.

Factors affecting fauna recovery in the Wheatbelt: Lake Magenta and Dunn Rock Nature Reserves

SPP 2006-009

Team members

K Morris

Context

This project is part of a larger program examining introduced predator control and sustained fauna recovery in the rangelands and south-west of Western Australia. In particular, this project will examine whether there has been a mesopredator release effect after several years of fox control, i.e. have other introduced/native predators increased in abundance and become a threatening process for fauna survival.

Aims

- Determine the causal factors responsible for the medium-sized mammal declines at Lake Magenta Nature Reserve, and identify the management required to slow these declines.
- Develop adequate introduced and native mammal monitoring protocols that will enable future changes in population abundance to be quantified and explained.

Summary of progress and main findings

- Report prepared synthesising results from the five mesopredator research sites.

Management Implications

- This project identified changes that could be made to fox baiting regimes to improve fox control.
- A reduction in fox activity through baiting led to an increase in feral cat activity indicating that effective fox and feral cat control will be required to allow the full range of native fauna to be re-established on wheatbelt reserves.
- Provided information to assist in the development of improved monitoring protocols for Western Shield.

Future directions (next 12 to 18 months)

Incorporate Lake Magenta results into the synthesis publication. This project has been completed.

Sustained fauna recovery in a fragmented landscape (Dryandra Woodland and Tutanning Nature Reserve)

SPP 2006-007

Team members

N Marlow, A Williams

Context

The trap success for woylies (*Bettongia penicillata*) in Dryandra Woodland and Tutanning Nature Reserve increased dramatically following the introduction of fox baiting in both areas during the 1980s. However, despite the maintenance of ongoing fox baiting, the annual Western Shield trapping for woylies revealed a decline in trap success of woylies after 2002. This project aims to identify the factors responsible for the decreased survival and recruitment of woylies, so that, if possible, additional management options could be implemented to reverse the woylie's downward population trend. These factors include predation from feral cats, pythons or raptors; ineffective fox control due to the 1080 loading of fox baits being or becoming too low; the uptake of fox baits by non-target species being too high; or because foxes have become bait shy.

Aims

- Determine the causes of woylie decline in a wheatbelt reserve.
- Test the mesopredator release hypothesis at the landscape and local scale (i.e. increased predation by feral cats, pythons or raptors in the presence of effective fox control).
- Test the effectiveness of current baiting regimes and identify if resident foxes are present.

Summary of progress and main findings

- The results from Dryandra / Tutanning have been incorporated into a report synthesising results from the five mesopredator research sites.
- A final report has been produced and several papers are about to be submitted for publication

Management Implications

- The development of effective operational cat control for Western Shield is of paramount importance for fauna conservation in the south-west of Western Australia as many species cannot persist in the presence of cat predation.
- When available, the cat control methods need to be combined with fox baiting to improve the efficacy of predator control and to afford the recovery of faunal populations.
- The current fox baiting regime using Probait is essentially effective and needs to be maintained to afford fox control. No differences in the uptake of Probait or dried meat baits by

foxes or non-target species were observed and so either bait type can be used in operational fox control programmes.

- There is no advantage to the fauna in increasing fox baiting intensity from 5 baits per km² to 50 km².

Future directions (next 12 to 18 months)

- Finalise and publish all relevant manuscripts, including the synthesis paper.
- This project has been completed.

The importance of fox, cat and native predator interactions to sustained fauna recovery in the northern jarrah forest: is there a mesopredator release effect?

SPP 2006-005

Team members

P De Tores

Context

Fauna recovery within Western Australia is largely dependent upon the effectiveness of localised and large-scale control programs for introduced predators. However, recent research and monitoring by Parks and Wildlife has demonstrated that the abundance, distribution and recovery of some species is unlikely to be a function of a single causal factor such as predation. Consistent with this hypothesis, some of the Department's Western Shield projects have not been able to demonstrate a response to fox control. In most of these cases there is insufficient information to determine why some programs have been unable to demonstrate a response to baiting programs or to determine why translocation programs have been unable to demonstrate success.

Various hypotheses have been proposed to explain these declines, but none is universally accepted and a combination of causal factors is likely. However, there was strong evidence that predation by cats increased when fox density was reduced. This phenomenon is well documented in ecological theory and is known as mesopredator release. This project was established in collaboration with the Invasive Animals Cooperative Research Centre (IA CRC) to assess whether cats have shown a mesopredator release in the presence of fox control within the northern jarrah forest.

Aims

- Test the mesopredator release hypothesis at the landscape and local scale.
- Assess the importance of other factors to fauna recovery and translocation success.

Summary of progress and main findings

- Incorporated the results from the northern jarrah forest into a report synthesising the research from the five mesopredator sites.

Management Implications

- Fox and cat control will need to be integrated through strategic control programs for both species.
- Broad-scale cat control in the south-west is not possible until a suitable bait is developed. It is likely that different cat control regimes will be required in different biomes, i.e. one baiting protocol will not suit all sites.
- The effectiveness of integrated baiting programs will need to be monitored through techniques suitable for the targeted species.

Future directions (next 12 to 18 months)

Completion of synthesis paper. This project has been completed.

Impact of cane toads on biodiversity in the Kimberley

SPP 2006-004

Team members

D Pearson

Context

Cane toads constitute a serious threat to the biodiversity of the Kimberley and yet little robust data are available to assess their impacts. An ARC-linkage project with the University of Sydney and Parks and Wildlife as the major partners identified taxa most at risk from the toad invasion. Research now focuses on potential techniques to reduce the impact of cane toads on the most susceptible native predators in the Kimberley.

Aims

- Monitor the impact of invading cane toads on populations of frogs, snakes and goannas in the east Kimberley.
- Field test conditioned taste aversion as a means to prevent the loss of native predators.

Summary of progress and main findings

- Continued monitoring native frogs in wetlands around Kununurra.
- Undertook trials of the taste aversion sausage and results indicate that these may have a use in preventing native fauna eating cane toads, particularly in island situations.
- In conjunction with the University of Sydney (Prof Rick Shine and PhD student Georgia Ward-Fear) and the Balanggarra rangers, undertook a 'teacher toad' trial on a landscape scale on the Forrest River floodplain. We tested if it was possible to get wild goannas to eat small toads to elicit a taste aversion reaction and so alter their behaviour.
- Provided input into considerations of the feasibility of a toad barrier near Broome relying on restricting access to water.
- Worked with regional staff to survey for toads and native predators on Adolphus Island.
- Published paper on behavioural responses of reptile predators to invasive cane toads in *Austral Ecology*.

Management Implications

- This project has identified which native species are most at risk from cane toads and management actions to reduce this risk can be targeted at these species.
- Taste aversion training using unpalatable sausages and/or teacher toads has been shown to be a potential management option to reduce consumption of cane toads by native fauna, including goannas, particularly on islands.

Future directions (next 12 to 18 months)

- Continuation of landscape scale 'teacher' toad trials with floodplain goannas this coming wet season.
- Quolls surveys on Adolphus Island with taste aversion training to improve survivorship now that toads have reached the island.

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

SPP 2003-005

Team members

D Algar, N Hamilton, M Onus, J Rolfe

Context

Control of feral cats is one of the most important native fauna conservation issues in Australia. Development of an effective broad-scale baiting technique, and the incorporation of a suitable toxin for feral cats, is cited as a high priority in the National Threat Abatement Plan for Predation of Feral Cats, as it is most likely to yield a practical, cost-effective method to control feral cat numbers in strategic areas.

Aims

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

Summary of progress and main findings

- Research into bait composition is continuing with the objective of further improving bait uptake. Chemical synthesis of several compounds that elicit a chewing response by cats is progressing and mould inhibitors to surface coat the bait are also being investigated.
- Feral cat baiting programs on the Fortescue Marsh (Pilbara) were conducted in 2012 and 2013. Both campaigns resulted in statistically significant declines in cat occupancy rates in the baiting area. A further baiting program was conducted this winter; the camera traps are currently being retrieved and the data downloaded.
- Research into the effectiveness of baiting strategies is continuing to be assessed under the temperate climatic conditions of the south-west at Cape Arid National Park. The baiting programs conducted over the past four years have contributed to an apparent stabilisation in the critically endangered western ground parrot population and significant population increases in number of other species, including the southern brown bandicoot.
- Stage 1 of the management plan for the control of cats on the tropical Christmas Island has been completed with all domestic cats having been desexed, microchipped and registered. Stage 2 of the plan is continuing and involves the removal of all stray/feral cats from the residential area and surrounds. Without implementation of Stage 2, a significant source of cats, particularly natal recruits, would be able to disperse into or reinvade vacated territories across the rest of the island. To date over 600 stray/feral cats have been removed. It is anticipated that Stage 3 of the plan - island-wide eradication of feral cats will commence in 2015/16. Significant improvements in nestling success of species such as the red-tailed and white-tailed tropicbird have occurred since commencement of the program, a direct result of cat removal from the shoreline colony.
- Work has been completed on the lure for the active camera traps. A combination of olfactory and visual attractants are used and have been shown to be successful in attracting cats to the camera traps across temperate, semi-arid and tropical environments. Also, a new audio lure is currently being developed as a further trap attractant.

Management Implications

- Development of effective baiting methods across climatic regions will ultimately provide efficient feral cat control at strategic locations across the state and lead to conservation benefits.
- Successful eradication of cats from a number of islands off the Western Australian mainland has occurred over the past ten years (i.e. Hermite, Faure and Rottnest islands), allowing the persistence of the native fauna of the islands and enabling effective reintroductions of mammals where necessary. Eradication of cats on Dirk Hartog Island will enable reconstruction of the mammal assemblages on the island.

Future directions (next 12 to 18 months)

Analyse baiting effectiveness at the various research sites and refine the method of operation where necessary.

Gilbert's potoroo (*Potorous gilbertii*) recovery plan

SPP 1996-008

Team members

T Friend, S Hill, T Button

Context

Gilbert's potoroo is the world's rarest marsupial. The *Gilbert's Potoroo Recovery Plan 2003–2008* provides a list of actions to improve the conservation status of this Critically Endangered species. This project involves, or has involved collaborative arrangements with, Parks and Wildlife South Coast and Warren Regions, South Coast NRM, universities (Murdoch, Edith Cowan, UWA and Adelaide), the Royal Zoological Society of South Australia, the Foundation for Australia's Most Endangered Species (FAME), private sponsors and the Albany-based Gilbert's Potoroo Action Group to implement conservation actions.

Aims

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

Summary of progress and main findings

- A census of the Mount Gardner population (Two Peoples Bay NR) of Gilbert's potoroos is conducted three times a year. Numbers remained stable from 2001 when this regime was introduced, until November 2013, when a significant decline was detected. Eleven potoroos, representing about 75% of the Mt Gardner population were known to be alive in November 2013.
- During 2005–2007, ten potoroos were transferred from Two Peoples Bay to Bald Island. Trapping between three and six times per year showed that the translocated population grew rapidly. Between 60 and 70 potoroos are known to be alive on the island, despite the removal of a total of 35 individuals since 2008 for translocations to the mainland. The majority (25) were transferred to the 380 hectare enclosure at Norman's Beach, Waychinicup National Park. The other six animals were released outside the fence into a fox-baited area.
- Monitoring of the population in the Waychinicup enclosure by trapping, radio-tracking and motion-activated cameras has shown that some of the potoroos use vegetation types floristically and structurally different to that occupied at Two Peoples Bay, and that breeding and recruitment are occurring.
- In November 2013, 16 potoroos were known to be alive in the enclosure, of which eight were born on-site.

Management Implications

- Results of the Bald Island translocation and subsequent monitoring indicate that a new self-sustaining population has been established at a site unaffected by introduced predators and lacking most native predators. This new population will provide better security for the species in the face of the greatest threat to its survival, wildfire at Two Peoples Bay. It also provides a source of potoroos for future translocations to secure sites.
- Establishment of potoroos at the Waychinicup enclosure in vegetation types different from those used at Two Peoples Bay implies that a wider range of potential translocation sites may be available than previously believed.

Future directions (next 12 to 18 months)

- Continue to monitor the Mount Gardner, Bald Island and Waychinicup National Park (enclosure) populations. Continue to monitor the enclosure for incursion by cats or foxes. Implement structured trapping to determine habitat use.
- Undertake trials of Eradicat® cat bait on non-target species at Two Peoples Bay and Waychinicup National Park.
- Evaluate further translocation sites, both on the mainland and on other islands.
- A paper on the population dynamics of Gilbert's potoroo at Two Peoples Bay will be submitted for publication.

PLANT SCIENCE AND HERBARIUM

DAVID COATES

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, ameliorating 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. This research is aligned to the information needs of the Department of Parks and Wildlife. Strong collaborative linkages exist with universities, cooperative research centres, CSIRO and other research institutions and the corporate sector. The program also includes the Western Australian Herbarium that houses the state collection of scientific specimens of plants, algae and fungi. Information in the collection underpins the conservation of the Western Australian flora. The Herbarium is responsible for: documenting and understanding the diversity of Western Australia's plants, algae and fungi; maintaining a research and archive collection of specimens of all species in these groups from throughout their range in Western Australia; helping the community, industry and researchers understand and identify plants, algae and fungi; contributing to, supporting and servicing the research, conservation and decision-making activities of the government; contributing to taxonomic research by Australia's and the world's scientific community; providing authoritative information to government, industry and the community via the FloraBase website and the Herbarium's information management systems.

Interactive key and taxonomic studies of Myrtaceae tribe Chamelaucieae

SPP 2013-052

Team members

B Rye

Context

Taxonomic revision is required in various plant groups to facilitate appropriate determination of their conservation status. The main group of plants under study comprises over 400 species of shrubs in the Myrtaceae. They are very poorly known at both the species and generic levels. The lack of an adequate taxonomy continues to impede their conservation, study (in fields other than taxonomy) and commercial utilisation. The other main groups under study are two genera of the Proteaceae (*Isopogon* and *Petrophile*) and one genus (*Pimelea*) in the Thymelaeaceae.

Aims

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

Summary of progress and main findings

- Papers on *Astartea*, *Calytrix*, *Cyathostemon*, *Hypocalymma*, *Verticordia* and miscellaneous new combinations (Myrtaceae: Chamelaucieae) were published in *Nuytsia*. A popular article was also published in *Kwongan Matters*.
- A paper on *Thryptomene* has been submitted.
- Several other papers are in preparation and an interactive key to Myrtaceae tribe Chamelaucieae has been continually updated, including new ecological data.

Management Implications

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

Future directions (next 12 to 18 months)

- Official release of the interactive key through publication of an introductory paper in *Nuytsia*. Hold a workshop to demonstrate the key.
- Submit papers on *Hypocalymma* and *Oxymyrrhine* (Myrtaceae) and a paper on several genera of Cyperaceae.
- Seek involvement with Flora of Western Australia projects and/or Australia-wide generic keys.

Biosystematics of fungi for conservation and restoration of Western Australia's biota

SPP 2012-031

Team members

N Bougher

Context

This project represents a new and timely effort to build the state's biodiversity knowledge base, and create and apply more comprehensive and accurate fungal scientific knowledge for conservation and management of the state's biodiversity.

Aims

- Generate and provide scientifically accurate and comprehensive taxonomic data for fungal taxa in Western Australia that are previously unrecorded, unidentified, misidentified, or ill-defined, particularly taxa of relevance to specific, current DEC conservation initiatives.
- Make available descriptive information about fungi taxa in published form and in online information systems.
- Improve access and uptake of scientific knowledge about fungi and thereby promote better awareness and understanding by scientists and community of the significance of fungal diversity and function in bushlands.
- Achieve greater taxonomic and geographic representation of representation of Western Australian fungi in datasets and as permanent vouchers at the Western Australian Herbarium.

Summary of progress and main findings

- Defined and illustrated morphological and molecular characteristics of a further 88 species of Australian Inocybaceae species, in readiness for upcoming monograph book.
- As a core part of this work, built global DNA nLSU-rRNA dataset including 474 sequences from Australasia, and rpb2 gene dataset including 367 Australasian sequences. Released 724 DNA sequences to GenBank.
- Released over 100 submissions for resolved new species of Inocybaceae to MycoBank.
- Published journal paper highlighting parallel agaricoid-secotioid species pairings of *Inocybe* from WA wheatbelt and North America.

Management Implications

The availability of scientifically accurate and comprehensive information about taxa of fungi in Western Australia will encourage and allow Parks and Wildlife and the community to incorporate knowledge of fungi into management practices. This includes regional biological surveys, managing the interdependent linkages between fungi and plants and animals, and a providing a better basis for assessment of the conservation status of fungi taxa.

Future directions (next 12 to 18 months)

- Continued taxonomic research defining and documenting species of the ectomycorrhizal fungi family Inocybaceae in Australia.
- Morphological and molecular phylogenetic data of individual collections of Inocybaceae will be generated and assessed then used to define species concepts.
- Construction and compilation of text and illustrative material to produce a complete manuscript that will be submitted to the external client (ABRS) for the target product, a monographic book on the Australian Inocybaceae for the *Fungi of Australia* series.

Understanding mulga

SPP 2012-026

Team members

B Maslin, J Reid, J Sampson, Prof R Rutishauser (University of Zurich), Dr J Miller (Australian National Herbarium)

Context

Mulga forms a significant component of rangelands vegetation. These species are crucially important to the structure, ecology and functioning of these systems, as well as being of economic importance. Mulga species, especially *Acacia aneura* itself, are notoriously variable, the taxonomic boundaries are poorly understood and identification of these taxa is extremely difficult. Understanding this variation, determining its causal factors and being able to reliably identify the taxa are critically important to the effective management, conservation and utilisation of this valuable resource.

Aims

Elucidate patterns of variation within species of the mulga group to provide a reliable means of identifying the taxa so that they may be effectively managed, conserved and sustainably utilised.

Summary of progress and main findings

- Western Australian Herbarium Reference Herbarium updated insofar as is possible.
- Mulga Workshops (x4) held in October 2013 were well-attended
- Electronic key produced on CD and distributed to Workshop participants.
- Mulga key (same as on CD) incorporated into WATTLE2 ver.2.2, which is now deployed on the web.
- Report prepared by Prof. C.H. Stirton (U.K.) on productive future research directions involving Mulga in W.A.

Management Implications

Clarification of the taxonomy of mulga species will facilitate their effective conservation.

Future directions (next 12 to 18 months)

- This project is now completed; however, the Stirton Report (see under Progress) has identified a number of lines for potential future work.

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

SPP 2012-021

Team members

C Yates

Context

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

Aims

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

Summary of progress and main findings

- Completed analysis of climate manipulation experiments (decreased rainfall and increased temperature) on plant demography across the soil depth gradient and synthesised results.

Management Implications

The project will provide projections of the likely risks of adverse effects of unavoidable climate change on plant species and communities in the Midwest Region and more generally for south-west Western Australia. The results of the study show that:

- decreased rainfall reduces woody species germination and seedling survival and growth and plant survival, flower and fruit production in mature vegetation;
- increased temperature reduces woody species germination and seedling survival and plant survival, canopy health and fruit production in mature vegetation;
- the magnitude of these changes varied among species from different plant functional types and was greatest in parts of the landscape where soil water is most limiting.

Under projected warmer and drier climates for the region there are likely to be declines in species richness and changes in composition of kwongan toward lower stature more drought tolerant species. Management should continue to focus on mitigating the risks and effects of interacting threatening processes, maintaining the genetic diversity of species to maximize potential for evolutionary adaptation, maintaining or enhancing ecological connectivity to maximize potential for species migration and identify the location of potential refugia where conditions remain suitable for the most vulnerable species to persist.

Future directions (next 12 to 18 months)

- Publish results from climate manipulation experiments in scientific journals.

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

SPP 2012-006

Team members

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 includes 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. It also includes the development of interactive keys to all Western Australian species in the three genera. Once complete, 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.

Summary of progress and main findings

- Substantial progress on the taxonomy of *Adenanthos pungens*.
- Papers on undescribed species of *Solanum* and *Swainsona* were completed and have been published.
- Two new species of *Westringia* were discovered and paper published.
- Draft paper in press on the discovery of two new *Ptilotus* species.

Management Implications

The taxonomy and identification of *Ptilotus*, *Gomphrena* and *Swainsona* is important for rangeland and arid land management as they are ecologically important genera in these regions. Many are annuals, and *Swainsona* is a nitrogen-fixing legume. Some species are useful indicators of ecological condition.

Future directions (next 12 to 18 months)

- Completion of descriptions of *Ptilotus* for the *Flora of Australia* treatment and preparation of further papers describing new taxa in *Ptilotus* and other genera.
- Further field studies to assist in the resolution of problematic groups, particularly the widespread *Ptilotus obovatus* species complex.
- Progress interactive keys to *Ptilotus*, *Gomphrena* and *Swainsona*.
- Paper on a new species of *Grevillea* from the Great Victoria Desert.
- Paper dealing with the synonymy of *Adenanthos pungens*.

The Western Australian Plant Census and Australian Plant Census

CF 2011-111

Team members

C Parker, L Biggs, T Macfarlane, M Falconer, U Sirisena, K Knight

Context

The Western Australian Plant Census (a component of WACensus) is the authoritative database of all names of plants in Western Australia, including synonyms created by taxonomic change. It is continually updated to reflect changes in our knowledge of the flora. The census constitutes the fundamental master list for many Parks and Wildlife processes and datasets, including the Threatened and Priority Flora databases maintained by the Species and Communities Branch, the Herbarium's specimen database, the Max database utility, FloraBase and NatureMap.

The Australian Plant Census (APC) is a project of the Council of Heads of Australasian Herbaria, designed to provide a consensus view of all Australian plant taxa. Until now plant censuses have been only state-based, which has made it difficult to obtain authoritative information on what species occur in

Australia as a whole, to obtain accurate national statistics, and to deal with differences in opinion and knowledge for taxa that cross state boundaries. In addition to working systematically through the vascular plant families, the APC process provides for updates as taxonomic changes or new findings are published. The consensus also extends from family and genus level to an overall classification of the plants that occur in Australia. As the APC project continues, the Western Australian Plant Census is updated to reflect the consensus view.

Aims

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

Summary of progress and main findings

- 295 plant names were added to the plant census, comprising 274 names formally published and 121 phrase names; 479 other edits were made to the census, and 51 species were assigned conservation status.
- WACensus updates were regularly distributed to over 254 registered Max users on a quarterly basis.
- The last major family processed for the APC (Orchidaceae) was progressed and is still ongoing.
- An update list was finalised for *Acacia* and taxonomic changes processed.

Management Implications

- All Parks and Wildlife systems using Western Australian plant names are based on, or integrated with, the WACensus database.
- Staff maintaining plant databases can use Max and the regular WACensus updates to check name currency.

Future directions (next 12 to 18 months)

The census currently includes names of all vascular plants, lichens, moss and algae, and future work will add liverworts and fungi.

The Western Australian Herbarium's specimen database

CF 2011-110

Team members

L Biggs, M Falconer, E McGough, K Knight, J Percy-Bower

Context

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

Aims

Capture, maintain and validate spatial, phenological, population and habitat data for all the herbarium's collections, enabling curation of the collection and providing core data for FloraBase and Parks and Wildlife decision support systems and research.

Summary of progress and main findings

- 8078 records were added to the specimen database, including 709 Priority Flora and 116 Threatened Flora.

- 27 requests for specimen data (species lists and label data) were processed for Parks and Wildlife officers, researchers and the public.
- 30590 specimen records were edited during this period as part of activities aimed at keeping the collection scientifically valid and up-to-date.

Management Implications

WAHerb represents the most comprehensive database on Western Australian plants available. This provides a source of information that managers can use for updates on biodiversity or conservation status, plant identification, clarification of plants in an area, and identification of knowledge gaps.

Future directions (next 12 to 18 months)

Editing will continue on the WAHerb database to maintain its currency with the herbarium collections, including checking the accuracy of existing records.

Herbarium collections management

CF 2011-105

Team members

K Knight, C Parker, K Thiele, L Biggs, R Cranfield, R Rees, P Spencer, M Falconer, R Davis, S Coffey, M Hislop

Context

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

Aims

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

Summary of progress and main findings

- 8078 specimens were added to the collection, which now stands at 751129, a 1.09% increase in holdings during this period.
- The major plant groups in the collection are as follows:

Taxonomic Group	Number of specimens (June 2014)	Increase since June 2013		
		#	% Group	% Overall
Myxomycetes	912	15	1.67	0.00
Fungi	24099	578	2.46	0.08
Lichens	17914	1424	8.64	0.19
Algae	23436	73	0.31	0.01
Liverwort and hornworts	2095	109	5.49	0.01
Mosses	6912	192	2.86	0.03
Ferns and fern allies	3716	31	0.84	0.00
Gymnosperms	2055	16	0.78	0.00
Flowering plants	669990	5640	0.85	0.76
Total number	751129	8078	1.09	1.09

- Loans and exchange: loans outward—909 specimens; loans inward—362 specimens; exchange outward—2801; exchange inward—1804 specimens.
- Volunteer participation was significant, totalling 7441 hours.
- Tasks managed by curation staff with the assistance of volunteers were as follows: general curation of specimens; mounting and labelling 5416 specimens; validation of names and distribution of incoming specimens; auditing, maintaining and adding to the Reference Collection.
- Reference Herbarium: maintained the facility, which has over 14643 specimens representing 11683 taxa and also added or replaced 158 specimens. 1088 visitors used this resource to identify plant specimens during this period.
- The Herbarium provided 190 high resolution scans of herbarium specimens to Parks and Wildlife district staff to aid in the identification and location of known and new populations of priority and threatened taxa.
- The Herbarium Identification Program provides identifications to a range of clients and specialises in taxa and specimens that clients find challenging. Our most significant clients included Parks and Wildlife, other government agencies, environmental consultancies, regional herbaria and the public.
- Educational role: provided tours of the herbarium for tertiary institutions, Parks and Wildlife staff, environmental consultancies and community groups.
- Scanned 5155 type specimens for the Global Plants Initiative to make accessible to the world's scientific community plant type specimens and other botanical resources for study.

Management Implications

- Maintenance and curation of the herbarium collections provides an authoritative inventory of the plant biodiversity of Western Australia.
- The collections are drawn upon constantly by Parks and Wildlife staff, consultants and others for validating specimen records from biological surveys and for assessing the conservation status of all native taxa.
- Many taxa in Western Australia are yet undiscovered, but many of these are already represented by specimens in the herbarium, awaiting recognition by taxonomists.

Future directions (next 12 to 18 months)

- Complete the scanning of the remaining 1000 type specimens in the collection for the Global Plants Initiative.
- Continue to maintain the collection to an authoritative standard for all users.

Biodiversity informatics at the Western Australian Herbarium

CF 2011-104

Team members

K Thiele, B Richardson

Context

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

Aims

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

Summary of progress and main findings

- Completed migration of FloraBase to a single database platform (MySQL), simplifying its management.
- Managed the migration of the spatial component of FloraBase so that it runs on Windows 7.
- Maintained FloraBase, including fixes for the Department name change, less error-prone publication of *Nuytsia* articles and Interactive Keys, Plant of the Month additions, and support for changes made to WACensus.
- Progressed development of a major revision of the management of user accounts, to avoid a dependence on old and deprecated software that can no longer be supported.
- Progressed development of a Specimen Accessioning Tool, which will allow users of FloraBase to determine whether specimens should be sent to the Herbarium for incorporation into the collection.
- Progressed development of a major overhaul to FloraBase's presentation of images, using images from ImageBank.

Management Implications

- FloraBase allows the community and Department staff to retrieve the most recent information on the name, features, status and distribution of the 13632 currently recognised native and naturalised Western Australian vascular plant taxa. Conservation efforts across the state are made more effective by access to this authoritative information.
- Involvement in national and international informatics collaborations enables Western Australia to participate fully in new developments in these areas, ensures that Western Australian data is made available to the broadest possible audience, and ensures that data from other sources can be integrated with local data for more effective research and analyses.

Future directions (next 12 to 18 months)

- Implement the third major version of FloraBase, determining to what extent it draws on or is implemented within ALA infrastructure.
- Add new content, including interactive keys for identification of plant groups at species level.
- Complete and release the Specimen Accessioning Tool.
- Develop further standards to facilitate and participate in national and international bio-infrastructure projects, such as ALA, NatureMap and other common online services.

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

SPP 2011-015

Team members

M Hislop, A Chapman, K Thiele

Context

Epacrid classification is undergoing fundamental reassessment at the generic level as new information on relationships is revealed. *Leucopogon*, in particular, is species-rich in Western Australia but is relatively poorly understood and includes many undescribed taxa, including ones of conservation significance. It is also clear that the genus cannot be maintained in its current circumscription, although

generic boundaries are still uncertain. This project will continue to describe new taxa in *Leucopogon*, *Melichrus* and other genera in the subfamily Styphelioideae and, in collaboration with partners in eastern Australia, work towards a generic reclassification of the subfamily.

Aims

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

Summary of progress and main findings

- A taxonomic update of the genus *Conostephium* published in *Nuytsia* with descriptions of four new species, including one with high conservation significance.
- A paper describing six new taxa in *Leucopogon* s.str., including four with conservation significance, published in *Nuytsia*.
- A new paper submitted to *Nuytsia* in which a new and apparently geographically restricted white-flowered species of *Brachyloma* is described.
- One new phrase-name in *Leucopogon* (*L.* sp. Lake Tay, a member of the *L. conostephiodes* group) added to FloraBase.
- A number of old epacrid loans have been returned from NSW Herbarium, the specimens redetermined and processed back into the collection.
- Collaboration with regional Flora Officers on the nominations of three epacrid species for threatened flora status: *Leucopogon* sp. Flynn, now assessed as threatened flora; *Leucopogon* sp. Ongerup, assessment pending; *Leucopogon nitidus*, assessment pending.
- Agreement has been reached with collaborators in eastern Australia to accept a broad circumscription of *Styphelia* which will encompass all elements of *Leucopogon* not belonging to *Leucopogon* s. str.

Management Implications

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

Future directions (next 12 to 18 months)

- Preparation of further papers describing new taxa in *Leucopogon* and other genera.
- Further field studies to assist in the resolution of problematic groups.

Strategic taxonomic studies in families including Epacridaceae, Rafflesiaceae, Rhamnaceae and Dilleniaceae

SPP 2011-014

Team members

K Thiele

Context

This project involves systematic research, particularly resolution of species boundaries and descriptions of new species, in a number of families of Western Australian plants. Describing new species, particularly conservation taxa, is of fundamental importance for conservation, as it provides an

underpinning for all other biodiversity research. The families studied in this project include taxa of high conservation and biodiversity significance.

Aims

- Collect and curate specimens from the Western Australian Herbarium collection in the target families.
- Assess species boundaries and describe new species.
- Document the conservation, taxonomic and nomenclatural status of species.

Summary of progress and main findings

- A paper describing *Hibbertia sericosepala*, a new species formerly known as *H. sp.* Gnangara, has been published in *Nuytsia*.
- A short communication in *Nuytsia* has reduced *Hibbertia sp.* Mt Lesueur to a synonym of *H. crassifolia*, as close examination shows that the phrase-named entity cannot be recognised as distinct.
- Two short communications, one dealing with the taxonomic status of a rare taxon, *Aldrovanda vesiculosa* in Australia, and one correcting some errors in descriptions and identification features for a rare species of *Rorippa*, have been published in *Nuytsia*.
- A paper describing a new species of *Spartothamnella* including a resolution of the taxonomic status of *S. sp.* Helena & Aurora Range, has been submitted to *Nuytsia*.
- Herbarium studies have led to the resolution of further new species in *Hibbertia*. Two of these, *H. sp.* Mt Adams and *H. sp.* Wheatbelt have been added to the WA Plant Census pending field work. Several other new or potential new species have been recognised and are in progress towards taxonomic papers.

Management Implications

Knowledge of species in Western Australia, and the ability to recognise them, is critical for assessing conservation status, prioritising species for conservation management and for conservation planning. In particular, resolving the taxonomic status of phrase-named (poorly-known) taxa and describing new species is essential as part of the documentation of the flora of the state.

Future directions (next 12 to 18 months)

The taxonomy of *Hibbertia* remains an important focus of this work, as many new species remain to be described in this large and relatively poorly known genus. Several new species have been recognised in this genus through herbarium studies, and field work conducted during spring 2014 will help resolve these and lead to further publication of new species.

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

SPP 2011-013

Team members

G Keighery

Context

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

Aims

- Provide informative, stable taxonomy of potentially conservation-dependent taxa to aid their conservation and management, especially rare flora.

- Ensure that new taxa discovered during biological surveys are curated and described where possible. Studies are being undertaken on *Adenanthos pungens*, *Calytrix breviseta*, *Hypocalymma angustifolium*, *Adenanthos eyeri* - *A. forrestii* - *A. ileticus* species complex, *Cynoglossum*, *Grevillea curviloba* and *Grevillea evanescens*.
- Update weed data for collections in the Western Australian Herbarium.

Summary of progress and main findings

- Workshops on prioritisation of localised, widespread and alert weeds undertaken in all nine Parks and Wildlife regions and districts.
- Several new weeds recorded for Western Australia.
- Paper on weeds on southern offshore islands in press.
- Papers on weedy *Banksia* species, status of *Typha orientalis*, and on *Heliophila* in Western Australia in press.

Management Implications

- *Typha orientalis* a weedy native not introduced alien.
- Comments on status of 23 new, potential and revised status species made for FloraBase.

Future directions (next 12 to 18 months)

- Taxonomic notes on *Hypocalymma*, *Adenanthos pungens* and *Cynoglossum* to be published.
- Taxonomy notes on *Calytrix breviseta* to be drafted.
- Four more species to be nominated as Threatened Flora.
- Taxonomy of *Lambertia orbifolia*, *Banksia brownii* and *Grevillea curviloba* to be resolved.

Assessment of genetic diversity, key population processes and evolutionary relationships in the banded iron formation endemic *Acacia woodmaniorum* and its close relatives

SPP 2011-007

Team members

D Coates, M Millar, M Byrne

Context

Acacia woodmaniorum is a recently described species endemic to the Blue Hills banded ironstone ranges of the Midwest Region. Known from approximately 29,000 plants and restricted to an area of about 40 km², the species is gazetted as a Declared Rare Flora. The entire species distribution is currently covered by exploration mining leases, hence potential impacts on population and species viability from proposed mining activities must be identified. Knowledge of genetic structure and gene flow will enable effective management of impacts on this species, and enable understanding of the flora of the banded iron formations.

Aims

- Determine levels and partitioning of population genetic variation within *Acacia woodmaniorum*.
- Identify key population processes, such as mating and dispersal, that influence future levels and patterns of genetic variation.
- Determine evolutionary relationships and distinctness of *Acacia woodmaniorum* and its closest relatives.

Summary of progress and main findings

- *Acacia woodmaniorum* maintains moderate genetic structure with an outcrossed mating system and high levels of pollen-mediated gene flow.

- A manuscript on genetic connectivity and diversity in *Acacia woodmaniorum* has been published in *Heredity*. A second manuscript on pollen dispersal and the mating system in *A. woodmaniorum* is under review for publication in *Annals of Botany*.

Management Implications

- Self-incompatibility and outcrossed pollen dispersal are likely to be important mechanisms in ensuring the maintenance of genetic diversity and connectivity in *A. woodmaniorum*.
- Any alteration to pollinator numbers, assemblages or behaviour that negatively affects the introduction of outcrossed pollen is likely to have a significant effect on the production of viable seed and reproductive success of populations.
- Augmentation of small populations or the establishment of restored populations with mixed seed sourced from a number of populations may alleviate any effect of mate limitation, provide increased levels of genetic diversity and greater adaptive potential for populations, while outbreeding depression is unlikely to occur if seed from different populations is mixed.
- Maintaining populations in a landscape context will be essential for ensuring genetic connectivity among populations across the species range.

Future directions (next 12 to 18 months)

- Publication of results will be finalised.
- This project is now complete.

Taxonomic studies in selected families, including Asteraceae, Celastraceae, Malvaceae, Proteaceae

SPP 2011-006

Team members

N Lander

Context

The Asteraceae is the largest of plant families. In Western Australia it is represented by some 583 species in 183 genera: 20% of Western Australian species of the family are endemic and 125 species are weeds. Genera and species of Asteraceae are notoriously difficult to identify, due to the small size of their florets and the complexity of their arrangement into compound heads.

Prior to the preparation of an account of *Olearia* Moench (Asteraceae) in the ongoing *Flora of Australia* series it is necessary to clarify the limits of a number of Western Australian species that are easily confused and have been difficult to distinguish, and to describe a number of new species of *Olearia* and related genera.

Aims

- Taxonomic revision and treatment of Australian members of the genus *Olearia*.
- Formal description of several unplaced (and as yet unnamed) Western Australian genera and species of Asteraceae, tribe Astereae.
- Construction of an interactive identification and information system incorporating morphological, spatial, phenological, habitat, edaphic, biological and illustrative data for Australian species of *Olearia*.
- Compilation of *Flora of Australia* accounts of *Erodiophyllum*, *Minuria*, *Kippistia*, *Olearia* and several currently undescribed endemic Western Australian genera of Asteraceae, tribe Astereae.
- Construction of an interactive identification information system for all Western Australian genera and species of Asteraceae.

Summary of progress and main findings

- Interactive key to the Western Australian genera of Asteraceae (now 188 genera) extended with further binary keys to species.
- Binary keys to species of the following genera reformatted and submitted to KeyBase: *Eclipta*, *Pentalepis*, *Pleurocarpea*.

Management Implications

The Asteraceae have a major centre of diversity in Western Australia, with some 582 species (in 188 genera) of shrubs and herbs occurring in virtually every environment. Over 80 are listed as conservation taxa. With the current flux in classification and taxonomy in a group difficult to identify to species level, an authoritative source of current information is fundamental to correctly managing the conservation taxa and the lands on which they occur. Additionally, the Astereaceae are represented in Western Australian by 125 weedy species, some of critical significance.

Future directions (next 12 to 18 months)

Further work on taxonomy of *Olearia* and production of an interactive key will be continued as a Research Associate project.

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

SPP 2011-002

Team members

R Butcher

Context

Tephrosia is a large, pantropical legume genus comprising c. 400 species of herbs and shrubs. Sixty-two taxa are currently recognised in the Eremaean and Northern Botanical Provinces of Western Australia; including 29 phrase-named taxa, with a number of species complexes requiring further study. *Tephrosia* specimens are frequently collected during vegetation surveys for proposed mining developments in northern Western Australia; however, many of them cannot be adequately identified as they belong to poorly-known, undescribed taxa or to species complexes. Their identification is further hindered by the absence of up-to-date taxonomic keys and of comparable specimens, as many species of *Tephrosia* grow in remote areas and are poorly collected. Identification difficulties inhibit the accurate assessment of each taxon's distribution and hence its conservation status.

Aims

- Resolve the taxonomy of *Tephrosia* in Western Australia using morphological and molecular approaches.
- Assess the conservation status of all Western Australian taxa.
- Prepare identification tools, including an electronic key to the genus.

Summary of progress and main findings

- Two new taxa were added to WACensus, one of which is endemic to the State.
- The taxonomic distinctness of *Tephrosia* sp. C Kimberley Flora was confirmed relative to the very similar Queensland taxon *Tephrosia* sp. Mt Isa.
- Three distinct forms were recognised in *T. remotiflora* in Western Australia, two of which are endemic.
- A paper providing a conspectus of *Tephrosia* in the Eremaean Botanical Province, including descriptions for 15 to 20 undescribed taxa, is in preparation.
- Images were obtained for 15 taxa, ten of which are undescribed, to be added to *ImageBank*.
- All *Tephrosia* specimens in the Reference Herbarium had their quality assessed and identifications reviewed in light of taxonomic changes, and all taxa for which there is sufficient material are again represented.

Management Implications

Providing names, scientific descriptions, illustrations and identification tools for the various *Tephrosia* in Western Australia will enable industry and conservation personnel to accurately identify taxa, thereby improving their management and the assessment of their conservation status. If it is found that the individual *Tephrosia* taxa can be identified through DNA barcoding, this method will enable sterile or poor specimens, often collected during botanical surveys, to be properly identified.

Future directions (next 12 to 18 months)

- Conduct further studies on poorly collected and taxonomically difficult species groups.
- Analyse *Tephrosia* DNA barcoding sequences in conjunction with researchers at the University of Guelph, to assess intra- and inter-specific variation and taxon relationships.
- Continue with the construction of written and electronic identification tools.

Taxonomy of selected families including legumes, grasses and lilies

SPP 2011-001

Team members

T Macfarlane, R Cranfield

Context

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

Aims

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

Summary of progress and main findings

- *Wurmbea* (Colchicaceae): continued field work to assess conservation status of poorly known species. Progress on paper writing. Three further new species recognised.
- Hydatellaceae: published two papers on germination and seedling structure in *Trithuria*; paper on biogeographic history of *Trithuria* published; field work for population genetic component of interim recovery plan for critically endangered species *T. occidentalis*.
- Poaceae: further field work and research collaboration on *Neurachne* and the evolution of C4 photosynthesis.
- *Thysanotus*: Paper describing a new species was published. Paper describing two new species in preparation. Continued field and laboratory work.
- *Lomandra*: two papers describing new species or clarifying taxonomy were drafted.
- Logania (Loganiaceae): a review of variation in *L. serpyllifolia* required further study, paper writing in progress.
- Haemodoraceae: paper drafted on new Kimberley species.
- Asparagales: paper submitted on a neglected taxonomically useful flower feature in several plant families.
- Lichens: work continued on Census updating; specimen collection and identifications of existing herbarium holdings; advising on the listing of conservation priority species; preparation for image incorporation into corporate systems; continuation of interactive key preparation.

Management Implications

- Identification of species known or suspected to have a restricted distribution will enable re-assessment of the conservation status and improve management effectiveness.
- Improved identification tools will enable more effective identification of species.

Future directions (next 12 to 18 months)

- Complete and submit papers describing known new species and investigate species known from only one or a few populations.
- Continue to revise plant groups and investigate via field and herbarium studies various putatively new species in order to improve knowledge of the flora, provide stable plant names and provide means of identifying species.
- Publish information on selected plant groups for general audiences.

Comparison of plant canker pathogen impact and climatic variables in Proteaceae on the south coast of Western Australia and evaluation of selected fungicides as a management tool for canker control in the declared rare flora *Banksia verticillata* and *Lambertia orbifolia*

SPP 2010-004

Team members

C Crane, B Shearer, C Dunne, S Barrett

Context

The contribution of canker fungi to stem, branch and plant death in southern Western Australia has largely gone unreported. Canker pathogens, both primary and facultative constantly take advantage of changes in environment and host susceptibility. Measurement of canker activity will provide direct measures of the mechanisms of climate change fluctuation on species distribution across the south-west.

Aims

- Advance the understanding of canker disease biology and epidemiology in native plant communities within the national parks of the South Coast Region of Western Australia.
- Monitor shifts in canker expression in relation to current and predicted climate change scenarios.
- Develop direct therapy methods for mitigating the impact of canker pathogens in high-value natural and translocated rare flora populations.
- Test for correlations of canker impact with climate variables.

Summary of progress and main findings

- Transects have been surveyed over four years and a general increase has been identified in both incidence and severity.
- *Neofusicoccum* spp., *Luteocirrhus shearii* and *Cryptodiaporthe melanocraespeda* have been identified as the main causal organisms in a disease complex responsible for increases in impact.
- One new monotypic genus and species of disease-causing canker fungus (*Luteocirrhus shearii*) has been described and appears unique to Western Australia.
- Growth parameters for the canker fungi have been determined.
- Seven fungicides have been rated for effectiveness against the cankers with the best two currently being trialled in the field.
- Significant correlations of canker disease and temperature have been identified in *Banksia baxteri* stands.

- In an infected *Banksia verticillata* population, a fungicide spraying program has reduced canker impact.
- In an infected *Banksia coccinea* population, a fungicide spraying program has failed to reduce canker impact.

Management Implications

- Cankers have been shown to be increasing in incidence and severity across the south-west and this may be associated with stress induced by climate change.
- Canker disease is threatening a number of *Banksia verticillata* populations and control measures will need to be addressed in those populations.
- Fungicides can be used selectively to reduce rates of lesion development and can initially be considered for trial application in high-priority threatened species.

Future directions (next 12 to 18 months)

- Investigate the endophytic role played by fungi prior to shift to pathogenicity.

Temperature thresholds for recruitment in south-west Western Australian flora

SPP 2010-003

Team members

A Cochrane

Context

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

Aims

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

Summary of progress and main findings

- Paper published in *Oikos* detailing the results of a common garden experiment investigating the impacts of warming and rainfall changes on seedling emergence and growth in four *Banksia* species.
- Paper published in *Seed Science Research* detailing results of a laboratory experiment investigating population variation in tolerance to increased temperature during seed germination in four *Banksia* species.
- A review paper on population variation in seed traits in the context of climate change accepted for publication in *Global Ecology and Biogeography*.
- Paper submitted to *Plant Ecology* describing effects of experimental treatments on seedling performance in four *Banksia* species.
- Assessment of the temperature niche for germination of four species used in *Banksia* woodland restoration completed.

Management Implications

- Developing a framework to assess seed viability under environmental change will assist in restoration.
- Incorporation of seed biology into threatened species translocations will improve recovery success.

Future directions (next 12 to 18 months)

- Finalise and submit paper on the influence of a climatic gradient on seed and leaf traits in four *Banksia* species.
- Finalise and submit paper on the effects of temperature and moisture manipulation of seed germination in populations of four *Banksia* species.
- Ongoing studies profiling the temperature niche for germination of a range of Western Australian species.

Systematics of the triggerplant genus *Stylidium*

SPP 2010-001

Team members

J Wege

Context

With almost 300 known taxa, the triggerplant genus *Stylidium* is one of the most abundant and diversified genera in Australia. Whilst 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 many new taxa awaiting formal description, numerous species complexes that remain poorly understood, and a number of nomenclature and typification issues that require resolution. Perhaps the most significant issue at this point in time is the lack of an identification guide and readily accessible diagnostic information for the known species in Western Australia, which hinders accurate identification by conservation personnel, botanical consultants and other stakeholders. This is especially concerning in the south-west region where 83 taxa are conservation-listed, the majority of which require further survey to understand the full extent of their distribution.

Aims

Improve the underlying taxonomic knowledge necessary for effective biodiversity management of the triggerplant genus *Stylidium* and to make this information readily accessible to stakeholders. The current project focus is on taxa occurring in south-western Australia.

Summary of progress and main findings

- A paper describing two new conservation-listed species (*S. oreophilum* and *S. lithophilum*) from the Stirling Range National Park was published in *Nuytsia*.
- A taxonomic revision of the reed triggerplants (*S. junceum* and allies) has been submitted to *Nuytsia*.
- A Threatened flora nomination for *S. applanatum* was prepared in collaboration with Wheatbelt regional staff, and a targeted survey of the Priority One species *S. hygrophilum* ms was conducted with South West regional staff.

Management Implications

- Taxonomic research, including field survey and the correction of misidentified herbarium specimens, has improved our understanding of the distribution, habitat requirements and conservation status of a range of triggerplant species.
- The publication of names, scientific descriptions and associated data for a range of new taxa and their relatives will facilitate their conservation and management.

Future directions (next 12 to 18 months)

- Progress interactive key and phylogenetic research.
- Prioritise and prepare threatened flora nominations.
- Conduct field work to improve taxonomic understanding of focus groups.

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

SPP 2009-009

Team members

J Huisman, C Parker

Context

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

Aims

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

Summary of progress and main findings

- The book *Algae of Australia: The Marine Benthic Flora of North-western Australia, 1. The Green and Brown Algae* has been completed and submitted for publication. This book includes full descriptions and illustrations of over 170 species of algae (three new), plus identification keys and colour images. Most sections are authored by J.M.Huisman, some in collaboration with international and national experts. It will be published in 2014.
- Continued generation of descriptions and illustrations for a second book in the series, *Algae of Australia: Marine Benthic Flora of North-western Australia, 2. The Red Algae*. The majority of the text and illustrations have been prepared and edited/formatted by Australian Biological Resources Study in readiness for publication in late 2015. This book will include descriptions of several hundred species, over 50 of which are new to science.
- Participation in a field survey by J.M.Huisman to Ashmore Reef, resulting in numerous new collections that will add several hundred specimens to the herbarium holdings. These collections include many new Australian and Western Australian records, including the rare species *Kallymenia maculata*.
- Several major papers have been published concerning aspects of the north-western Australian marine flora, including revisions to the red algal family Liagoraceae and the genera *Sargassum*, *Tricleocarpa*, and *Caulerpa*.

Management Implications

- Enhanced knowledge of marine biodiversity allows a more accurate assessment of management and development proposals.
- 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.

Future directions (next 12 to 18 months)

- Further surveys of the marine algae of remote Western Australian locations. In late 2014 this will include the offshore Rowley Shoals.
- Publication of papers describing new and existing genera, species and other categories; contributions to FloraBase.
- Finalise production of *Algae of Australia: The Marine Benthic Flora of North-western Australia, 2. The Red Algae*, to be published by the Australian Biological Resources Study in 2015.

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

SPP 2009-008

Team members

J Huisman, C Parker

Context

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

Aims

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

Summary of progress and main findings

- Numerous descriptions at all taxonomic levels have been prepared, as part of the completed book *Algae of Australia: The Marine Benthic Flora of North-western Australia, 1. The Green and Brown Algae*. These will be uploaded to FloraBase once the book has been published in 2014.
- Further descriptions of red algae have been completed as part of the in-progress book *Algae of Australia: The Marine Benthic Flora of North-western Australia, 2. The Red Algae*. This book will be completed and published in 2015, at which time all new descriptions will be uploaded to FloraBase.
- Numerous additional *in situ* and microscopic images of marine algae have been taken. Over 200 new images have been uploaded to ImageBank, in readiness for proposed changes to FloraBase.
- Several hundred specimens have been added to the herbarium collection; these are primarily newly recorded species or specimens from remote locations and thus enhance distribution data.

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 will allow a more accurate assessment of management proposals/practices.

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

Future directions (next 12 to 18 months)

- Finalise coding of interactive key.
- Continue collating existing species descriptions and write new descriptions for uploading to FloraBase.
- Upload additional marine plant images to ImageBank/FloraBase.

An investigation of the epidemiology and use of novel phosphite application techniques in *Phytophthora cinnamomi* infestations in the national parks of the South Coast Region of Western Australia

SPP 2009-007

Team members

C Dunne, B Shearer, C Crane

Context

Determination of the biology and epidemiology of *Phytophthora cinnamomi* in the South Coast Region is important for implementing appropriate management options for the control of this pathogen. Further, understanding of the efficacy of high-intensity phosphite for the control of *P. cinnamomi* would provide more options for the management of infested areas.

Aims

- Advance our understanding of disease biology and epidemiology of *P. cinnamomi* in the native plant communities within the national parks of the South Coast Region of Western Australia.
- Demonstrate the use of novel phosphite control techniques to reduce the impact of *P. cinnamomi* within the Threatened Ecological Communities of the Stirling Range National Park and Bell Track infestation in the Fitzgerald River National Park.

Summary of progress and main findings

- Completed monitoring for a further year of two field trials within *P. cinnamomi* disease centres in native plant communities within Fitzgerald River, Gull Rock and Stirling Range national parks on the south coast of Western Australia. The first trial investigated the temporal and spatial soil inoculum dynamics of *P. cinnamomi*; the second trial determined the efficacy of the strategic high-concentration phosphite application to reduce autonomous disease centre expansion. *P. cinnamomi* demonstrated significant spatial and temporal variation between and within the three sites due to differences in plant community composition, soil properties, hydrology, topography and climate.
- The containment strategies deployed at Bell Track and Pabelup Drive within the Fitzgerald River National Park continue to contain the disease centre within its current catchment boundaries. Many of the novel techniques trialled, including subterranean metham sodium fumigation, root impervious membranes, hydrological engineering controls and strategic phosphite treatment, are proving highly effective.
- Undertook plant tissue analysis using Gas Chromatography-Mass Spectrometry tracking the fate of phosphorous at the aerial spraying targets in the Stirling Range National Park and Gull Rock National Park.
- Another containment project is currently being implemented at Muchea East priority protection area, specifically within Ippollo Nature Reserve.

Management Implications

- The epidemiology of *P. cinnamomi* varies significantly between the different plant communities across the south-west of Australia, which includes forests, woodlands and heathlands.

Understanding the factors that affect epidemiology of the pathogen greatly improves predictions for the spread of *P. cinnamomi* and resulting impacts, and allows for site-specific management procedures to be developed for defined management goals. Integrated management strategies for specific areas that combine commonly-used and novel control techniques can significantly increase the likelihood of management success.

- A number of novel control techniques were shown to be effective methods for protecting disease-free areas, reducing the rate of spread within partially infested areas and reducing the impact of the pathogen. The techniques developed also have applicability for the management of *P. cinnamomi* during mining, extractive industries, forestry, road construction, nursery production, horticulture and bushland revegetation projects.
- There is a need for a more consistent application of hygiene policies and improved hygiene strategies to reduce the spread of pests, weeds and diseases within Western Australian native ecosystems.

Future directions (next 12 to 18 months)

- Continue to monitor the containment and eradication trial sites.
- Finalise implementation of a containment project at loppollo Nature Reserve in the Muchea East priority protection area.

Taxonomic resolution and description of new plant species, particularly Priority Flora from those areas subject to mining in Western Australia

SPP 2009-006

Team members

J Wege, M Hislop, R Butcher, K Shepherd

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 c. 1500 putatively new and undescribed taxa in Western Australia, a significant proportion of which are poorly known, geographically restricted and/or under threat (i.e. Threatened or Priority Flora). The lack of detailed information on these taxa makes accurate identification problematic and inevitably delays the Department's ability to survey and accurately assess their conservation status.

Aims

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

Summary of progress and main findings

- A paper describing *Scaevola xanthina*, a localised endemic from the South Coast region, was published in *Nuytsia*.
- A paper describing a new, rare species of *Gastrolobium* from the South West region was submitted to *Nuytsia* for publication.
- A paper recognising the informally named *Spartothamnella* sp. Helena & Aurora Range (P.G. Armstrong 155-109) as a new species was submitted to *Nuytsia* for publication.
- A paper presenting the results of a multivariate morphometric study of taxon boundaries among Threatened and Priority-listed species of *Synaphea* endemic to the Swan Coastal Plain was submitted to *Australian Systematic Botany*. Four new species of conservation concern will be described.
- Names added to Western Australia's vascular plant census include *Dampiera* sp. Jaurdi (D. Angus DA 268) and *Philothea* sp. Bremer Range (E. Adams EA 659), two Priority One taxa discovered during survey work associated with a mining developments in the Coolgardie bioregion and the highly prospective Bremer Range respectively.

- Survey for the Priority One species *Stylidium hygrophilum* was conducted in conjunction with South West regional staff with a view to nominating this species as Threatened.
- A paper summarising the achievements of this strategic taxonomy initiative was submitted to Biodiversity and Conservation.

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 (next 12 to 18 months)

- Identify and formally describe new taxa of conservation significance.

Development of interactive identification platforms and content

SPP 2007-014

Team members

K Thiele

Context

Botanical identification keys are important tools that allow a wide variety of people—researchers, Parks and Wildlife staff, consultants, students and members of the general public—to identify plants. Good keys are particularly important in Western Australia in the absence of a complete Flora for the state. This project is developing, in conjunction with botanists and other members of the herbarium community, a range of computer-based, interactive identification keys for various groups of Western Australian plants, using the Lucid software tools. Completed keys are being published on FloraBase for community-wide access.

Aims

Develop user-friendly and accurate identification keys for important groups of Western Australian plants.

Summary of progress and main findings

- Corrections and further additions to keys to the families Goodeniaceae, Proteaceae and Haemodoraceae in Western Australia have been completed and made available to users.
- A key to all Western Australian species in the family Lamiaceae (which includes genera such as *Hemiandra*, *Hemigenia* and *Prostanthera*) has been completed and made available for use.
- Coding for a key to all Western Australian species of the difficult family Restionaceae has been completed and the key is being tested.
- A new key to the Western Australian species of the large, important and difficult family Malvaceae has been commenced.

Management Implications

The ability to accurately identify plant species in Western Australia is critical for conservation planning and management.

Future directions (next 12 to 18 months)

- Continue to correct and improve all keys as a result of user feedback.
- Bring the key to Restionaceae online in FloraBase and make available to users.
- Progress the new key to Malvaceae.

Conservation status and systematics of Western Australian *Acacia*

SPP 2003-008

Team members

B Maslin, J Reid

Context

Acacia species are coming under increasing consideration for salinity control and revegetation programs, and for their importance in the management of remnant vegetation. Understanding their biology and taxonomy is important for their use in restoration and for their effective conservation.

Aims

Undertake research to provide taxonomic and other advice to enable the effective conservation of *Acacia* and for the use of *Acacia* species in restoration.

Summary of progress and main findings

- Curation of the Western Australian Herbarium *Acacia* collections is ongoing and forms the basis for re-assessment of the conservation status of the Western Australian taxa.
- Papers published describing new species: (1) *Acacia gibsonii* from south-west WA, (2) *Acacia equisitifolia* from Northern Territory, (3) 13 new species of *Acacia* from the Kimberley region, WA and adjacent Northern Territory.
- Five manuscripts submitted for publication in *Nuytsia* describing 17 new species of *Acacia* from WA.
- Three papers published containing new *Vachellia* and *Senegalia* combinations: (1) for Southeast Asia and China, (2) for South Asia and the Arabian Peninsula, (3) *Vachellia bolei* combination.
- Review of manuscript containing revision of *A. microbotrya* undertaken.

Management Implications

- Identification of *Acacia* species that are key components of ecosystems will provide important options for restoration programs.
- Taxonomic studies, descriptions of new species and collection curation are key activities in the ongoing assessment of the conservation status of Western Australian *Acacia* taxa.

Future directions (next 12 to 18 months)

- Publish *Acacia microbotrya* revision.
- Complete and publish taxonomic revision of *Acacia saligna*.
- On-going description of miscellaneous new Western Australian *Acacia* species.

Genetic and ecological viability of plant populations in remnant vegetation

SPP 2002-001

Team members

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

Context

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

Aims

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

Summary of progress and main findings

- A paper detailing the genetic structure in the *B. sphaerocarpa* study area is in preparation.
- Paper on the impacts of fragmentation on pollen dispersal and genetic diversity in *Calothamnus quadrifidus* ssp. *teretifolius* is in press in *Heredity*. Fragmentation has had little impact on patterns of pollen dispersal among populations, but reduced genetic diversity and changed patterns of pollination within populations resulted in increased correlated paternity in degraded remnants compared to intact remnants.
- Paper on reproductive biology and demography in *C. quadrifidus* ssp. *teretifolius* was published in *Australian Journal of Botany*. Reproductive output was high but highly variable with no relationship to population size, degree of isolation or fragment size. Seedling recruitment was evident in remnants with an intact understorey, but there was consistent widespread failure of seedling and juvenile recruitment in degraded roadside remnants that also showed significant mortality of reproductive adults. In these degraded remnants recruitment failure appears to be the primary cause of species decline.
- Analysis of the genetic diversity, mating system and reproductive biology of *Hakea oldfieldii* has been completed. The three population areas in Perth Hills, Busselton and south coast showed significant genetic divergence as expected but there was also significant population divergence within these areas indicating low historical connectivity.
- Low diversity is associated with historical processes rather than recent fragmentation. Populations were predominantly outcrossed even when severely reduced in size, indicating little effect of inbreeding in small populations, but reproductive parameters were higher in small populations with intact vegetation compared to disturbed sites, highlighting effects of understorey on pollinator abundance and behaviour. Two draft papers have been prepared.

Management Implications

- The ability to rapidly and accurately assess the conservation value of a vegetation remnant is a critical step in landscape management aimed at integrating the goals of conservation and agricultural production. Currently much of this assessment is based on best guesses using anecdotal species-specific evidence, on the general principle that bigger is better, and on simple presence and absence data that take little account of long-term remnant trajectories. Improved accuracy of assessment of long-term persistence of broad classes of plant species will facilitate improved prioritisation of remnants for conservation and therefore better allocation of limited management effort.
- Establishment of realistic empirically-based goals for remnant size, shape and landscape configuration that maximise regional persistence of plant species will allow more efficient conservation efforts at the landscape level by facilitating cost-benefit analyses for remnant management and restoration work.
- The *Hakea oldfieldii* study showed that conserving populations in intact habitat is a high priority to maintain the genetic and ecological processes in naturally fragmented and insular species. Management interventions, such as enrichment planting to increase the diversity of pollen

donors, should also include habitat and understorey restoration to facilitate effective mating patterns. Seed collection should prioritise populations with intact habitat to maximise genetic diversity.

Future directions (next 12 to 18 months)

- Submit manuscript on the genetic structure of *B. sphaerocarpa* for publication.
- Write papers on mating system variation and reproductive output in *Eremaea pauciflora* and *Eucalyptus wandoo*, and genetic diversity in *E. wandoo* and *C. quadrifidus*.
- Finalise papers on genetic diversity, pollen dispersal and mating systems in *Banksia nivea* ssp. *uliginosa*.
- Finalise papers on reproductive biology and demography in *B. nivea* ssp. *uliginosa*.

Translocation of critically endangered plants

SPP 2001-004

Team members

L Monks, R Dillon, D Coates, T Llorens

Context

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

Aims

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

Summary of progress and main findings

- Infill planting was completed for translocations of three Critically Endangered plant species and new translocation sites were set up for two critically endangered plant species.
- Monitoring was undertaken for 40 sites of 26 taxa translocated in previous years.
- A meta-analysis of flora translocation data from across the Department has been completed. Two publications based on these data are in preparation: one an overview of translocation outcomes in Western Australia has been drafted and the drafting of the other, a review of translocation methods, is well underway.
- Assisted departmental district and regional staff plan and implement a range of flora translocations.

Management Implications

- Translocations lead to the improved conservation status for threatened flora, particularly Critically Endangered plant taxa.
- The improved awareness of best-practice translocation methods for Parks and Wildlife staff and community members undertaking such work will lead to greater translocation success.
- 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 that resources can be confidently re-allocated to new translocation projects.
- Ongoing monitoring of translocations is providing information on the success of methods used and the probability of long-term success. Close collaboration with district and regional staff on

this project then enables this information to be used immediately in other flora translocation projects.

Future directions (next 12 to 18 months)

- Continue the planting of experimental translocations of Critically Endangered plant species and other Threatened Priority Flora where further translocations are deemed necessary.
- Continued monitoring of threatened flora translocations and further development of criteria for evaluating success, such as PVA, mating system and genetic variability analysis.
- Complete a review on translocation outcomes in Western Australia and a review on translocation methods.
- Publish *Lambertia orbifolia* PVA modelling study, and collect data for development of PVA model for translocated and natural populations of *Acacia cochlocarpa* subsp. *cochlocarpa*.

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

SPP 2001-001

Team members

D Coates, M Byrne, McArthur

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.

Aims

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

Summary of progress and main findings

- A paper is in preparation on significant genetic structure in *Banksia brownii* associated with three geographically distinct population groups, and the loss of substantial genetic diversity through the extinction of populations across the species distribution covering a range of habitats.
- Data analysis on mating system variation in two sister triggerplant species (*Stylidium affine* and *Stylidium maritimum*) with contrasting breeding systems has been completed and a paper is now being drafted.

Management Implications

- Assessment of genetic variation will inform prescriptions for the prevention of inbreeding and maintenance of genetic variation in small fragmented populations of rare and threatened plants, and will facilitate strategies for managing inbreeding and loss of genetic diversity during translocation programs.
- Translocation programs for *Banksia brownii* should continue to mix seed collections from within the three eco-geographic regions, but translocations should not yet be established with seed

mixes from different regions. Further translocations using seed collected from the now extinct eastern Stirling Range populations should be considered given the high levels of genetic diversity found in those populations.

Future directions (next 12 to 18 months)

- Submit paper on genetic structure and the impact of localised extinction on genetic diversity levels in *Banksia brownii*.
- Submit paper on the mating system in two *Stylidium* species, *S. affine* and *S. maritimum*.

The population ecology of critically endangered flora

SPP 2000-015

Team members

C Yates

Context

South-west Western Australia is a global hotspot of plant diversity. Determining the relative importance of multiple threatening processes, including the interactions between fragmentation and small population processes, fire regimes, weed invasion and grazing regimes, is critical for conservation and management of threatened flora (Declared Rare Flora) and Threatened Ecological Communities.

Aims

Determine the critical biological factors and the relative importance of contemporary ecological interactions and processes that limit population viability and persistence of threatened flora, particularly Critically Endangered species and other key plant species occurring in Threatened Ecological Communities.

Summary of progress and main findings

- Published findings of the Montane Heath and Thicket community study in a chapter on long term trends in Australian heathlands in the book "*Biodiversity and Environmental Change: Monitoring, Challenges and Direction*".
- Used the findings of the Montane Heath and Thicket community study to assess the conservation status of the community with the new IUCN Red List for Ecosystems criteria and submitted a manuscript for publication in a special edition of *Austral Ecology*.
- Continued monitoring the demography of the Critically Endangered *Verticordia staminosa* ssp. *staminosa* in relation to a drying climate in south-west Western Australia.
- Commenced a study of micro-climate in the Ravensthorpe Range to develop climatic layers at appropriate scales for modelling the distribution of short range endemics under the influence of a projected warmer and drier climate.

Management Implications

The long-term monitoring of the eastern Stirling Range Montane Heath and Thicket community and comparison with historical sources has demonstrated dramatic changes in the community as a consequence of *P. cinnamomi* and the recent fire regime. The outcome is a less diverse thicket community that still has significant conservation values. Continued management of *P. cinnamomi* through phosphite application and managing the fire return interval will be critical to conserve the remaining values of the thicket, together with an *ex situ* conservation program for the most threatened species.

Future directions (next 12 to 18 months)

- Continue to write up and publish research on the eastern Stirling Range Montane Heath and Thicket Community.
- Continue monitoring *Verticordia staminosa* ssp. *staminosa*.
- Establish micro-climatic sensor array network in the Ravensthorpe Range.

Susceptibility of rare and endangered flora to *Phytophthora*

SPP 1999-019

Team members

B Shearer, C Crane

Context

Determining the susceptibility of threatened flora to *Phytophthora cinnamomi* is important for prioritising flora at risk of infection and for implementing ecologically appropriate control options for the management of *P. cinnamomi*. This study was designed as a series of yearly testing of threatened flora as germinants become available from the Threatened Flora Seed Centre.

Aims

- Determine variation in susceptibility to *P. cinnamomi* between and within families.
- Identify within-species variation in susceptibility.
- Rank taxa according to susceptibility to identify those at risk.

Summary of progress and main findings

- Paper on spatio-temporal variation in invasion of woodlands and forest by *Phytophthora cinnamomi* published.
- Two threatened species added to susceptibility database of 200+ taxa.

Management Implications

Identification of flora at risk of infection by *P. cinnamomi* will enable quantification of the threat of this pathogen to flora conservation.

Future directions (next 12 to 18 months)

- Update database and analyse trends within database.
- Continue writing up and finalise all publications.

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

SPP 1999-010

Team members

A Cochrane, A Crawford, A Monaghan, D Coates, L Folan

Context

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

Aims

- Provide a cost effective and efficient interim solution to the loss of plant genetic diversity by collecting and storing seed of rare and threatened Western Australian plant species, and thereby provide a focus for flora recovery.
- Increase knowledge of seed biology, ecology and longevity.
- Incorporate all information into a corporate database (WASEED) 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.

Summary of progress and main findings

- 294 seed accessions lodged at the Threatened Flora Seed Centre (124 Declared Rare Flora [DRF], 48 Priority Flora and 122 common).
- Total number of accessions stored is 4232 (2030 DRF, 1052 Priority and 1150 common).
- Seeds of 77% of DRF and 22% of Priority taxa in secure storage.
- 167 accessions cleaned and stored (65 DRF, 41 Priority and 61 common accessions).
- 30 germination tests conducted (21 DRF, 5 Priority and 4 common accessions).
- Provision of seedlings of nine Critically Endangered species and one common species for translocation.
- Seed quality assessed for over 350 collections (Swan Region's *Banksia* Woodland Restoration Project).
- Seed collection of 12 species (30 collections) at risk due to *Phytophthora cinnamomi*.
- Seed of 65 *Eucalyptus* species provided to Sydney University for Myrtle Rust research.
- Article in *Australasian Plant Conservation* addressing Target 8 of the Global Strategy for Plant Conservation in Western Australia.

Management Implications

Seed conservation supports the survival of species in the wild by providing the genetic material for reintroduction; seed is provided for translocations of rare species and for restoration of *Banksia* woodland. Providing seed of WA *Eucalyptus* species will assist the determination of Myrtle rust susceptibility for those species. Provision of seed biology and ecology data increases the success of recovery of threatened flora, particularly through knowledge of pre-treatment stimulate germination.

Future directions (next 12 to 18 months)

- Ongoing collection of seed of threatened species for long-term conservation and use in reintroductions.
- Germination testing, storage and monitoring of existing collections.
- Ongoing research into seed biology and seed storage behaviour of threatened plant taxa.
- Ongoing collaboration with the Millennium Seed Bank Project, Royal Botanic Gardens, UK, through the Australian Seed Bank Partnership.
- Provide seed storage and seed testing service for the *Banksia* Woodland Restoration Project.

Australian wattle identification

SPP 1999-005

Team members

B Maslin, J Rogers, C Parker, K Thiele

Context

An electronic identification key called WATTLE was published (on CD) in 2001 by Maslin and others; it enabled quick and accurate naming of taxa of Australian *Acacia*. In the past decade about 50 new taxa of *Acacia* have been formally published and therefore WATTLE is becoming outdated and its effectiveness thus reduced. A funding opportunity to update WATTLE and deploy it on the web has been provided through the Atlas of Living Australia (ALA). This enhanced version of the key (called WATTLE2) will be more complete, have greater functionality and will be easier to maintain into the future.

Aims

Update the WATTLE identification key and deploy it on the web through facilities provided by ALA.

Summary of progress and main findings

An updated version of the key, WATTLE2 ver. 2.2, has now been deployed on the web and is available at Lucid Central website. This version includes all described taxa of Australian *Acacia* (including those in press as of June 2014). Also, each taxon now contains hyperlinks to the most current description, nomenclature, distribution and images.

Management Implications

Accurate identification of *Acacia* species is fundamental to effective nature conservation and natural resource management programs.

Future directions (next 12 to 18 months)

This project is now complete. Currency of the database will be maintained.

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

SPP 1998-003

Team members

M Byrne, T Llorens, D Coates, N Gibson, B Macdonald, M Hankinson, S McArthur, K Shepherd, R Butcher, R Binks, K Thiele, M Millar

Context

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

Aims

- Provide genetic information for the conservation and management of Western Australian flora, especially rare flora.
- Determine taxonomic identity of populations in the *Synaphea stenoloba* complex across the Pinjarra Plain.
- Determine level of differentiation between populations of *Eremophila microtheca* and *E. rostrata* to inform taxonomic status.
- Determine the level of differentiation in *Calothamnus quadrifidus* to assist in the taxonomic revision of the group.
- Clarify the taxonomic status of *Platytheca* sp. Sabina, *Hakea* aff. *prostrata*, *Pityrodia* sp. Yilgarn, and *Hydrocotyle scutellifera* and associated taxa.
- Determine the genetic diversity and genetic structure in *Lepidosperma* sp. Parker Range and *L.* sp. Mt Caudan.

Summary of progress and main findings

- A paper has been submitted to the *Botanical Journal of the Linnean Society* showing that there is significant population genetic structure in *Eremophila microtheca* and *E. rostrata* which supports subspecies entities in *E. rostrata* and indicates a taxonomic assessment is required for *E. microtheca*.
- Analysis of AFLP markers for putative taxa of *Synaphea* from the Pinjarra Plain has identified genetic discontinuities between populations to inform taxonomic revision.
- Additional samples were analysed in a phylogeographic study of *Calothamnus quadrifidus* that confirmed the phylogeographic patterns indicating the presence of historical refugia in the Kalbarri/Shark Bay region, along the south coast and on the inland granite outcrops and

greenstone ranges. Haplotype distribution reflecting evolutionary patterns supports the recent taxonomic revision of the species. A paper has been accepted for publication in *Heredity*.

- Analysis of genetic diversity in *Calothamnus quadrifidus* using AFLP markers was completed, showing patterns of genetic structure in the complex that are consistent with taxonomic revision.
- Analysis of genetic diversity has been undertaken in *Lepidosperma* sp. Parker Range and *L.* sp. Mt Caudan. Diversity within populations is moderate with high differentiation between populations. Possible clonality was suspected in these species due to very low seed set and plant structure. Assessment of individual diversity in plots at two populations within each species revealed some clonality in *L.* sp. Parker Range but individual genetic identities in plants of *L.* sp. Mt Caudan. Two papers have been submitted to *Annals of Botany*.

Management Implications

- Assessment of the genetic structure within collections of *Synaphea* from the Pinjarra Plain will inform taxonomic revision and determine the identity of questionable populations of rare taxa.
- Assessment of genetic differentiation in *Eremophila microtheca* and *E. rostrata* confirmed sub-specific taxa enabling assessment of conservation status.
- Assessment of genetic differentiation in *Calothamnus quadrifidus* has supported taxonomic revision of the group.
- Resolution of the taxonomic status of *Pityrodia scabra* subsp. *dendrotricha* (previously *Pityrodia* sp. Yilgarn) has enabled conservation assessment as Priority Three, as it is known from several populations that are not under immediate threat.
- Clarification of taxonomic status of *Platytheca* sp. Sabina, *Hakea* aff. *prostrata*, and *Hydrocotyle scutellifera* and associated taxa will enable evaluation of conservation status and implementation of conservation actions if required.
- High genetic diversity, low levels of clonality and small clone size in *Lepidosperma* sp. Mt Caudan indicate germplasm collections for conservation purposes should be taken at least one meter apart. Lower diversity, moderate levels of clonal reproduction and greater clone size in *L.* sp. Parker Range suggest germplasm collections should be at least four meters apart and comprise all populations.

Future directions (next 12 to 18 months)

- Publish *Eremophila microtheca* and *E. rostrata* study and complete morphological assessment for *E. microtheca*.
- Taxonomic revisions of *Platytheca* sp. Sabina, *Hakea* aff. *prostrata*, and *Hydrocotyle scutellifera* and associated taxa will be completed.
- Identification of taxonomic entities in the *Synaphea* complex of the Pinjarra Plain will be completed.

ECOSYSTEM SCIENCE

LACHIE MCCAW

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

Understanding the changing fire environment of south-west Western Australia

SPP 2014-001

Team members

L McCaw, B Ward

Context

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

Aims

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

Summary of progress and main findings

- Models to predict daily occurrence of human-caused bushfires from weather, fuel moisture and human behavioural factors were developed for Swan, South West and Warren regions and published in a paper in the *International Journal of Wildland fire*.
- A database of lightning fire activity in Frankland, Donnelly and parts of Blackwood district for the period 1977–2013 was developed to facilitate analysis of trends and spatial patterns in ignition and area burnt.
- A collaborative study was commenced with the Centre for Australian Weather and Climate Research to investigate climatic factors associated with lightning ignition.

Management Implications

Understanding the factors that influence the location and timing of bushfire ignitions is important for developing effective management strategies to minimise the risks posed by unplanned fires, and to guide the level of resourcing required for bushfire suppression in different management areas.

Lightning is an important cause of bushfire ignition in south-west Western Australia and the area burnt by lightning-caused fires has been disproportionately large relative to the number of ignitions during the past decade. Better understanding of the links between climatic patterns and lightning ignition could

provide advance warning of above-normal activity and the opportunity for improved preparation and resource deployment.

Future directions (next 12 to 18 months)

- Analyse data on temporal and spatial patterns of lightning ignition in the Warren Region and prepare a draft manuscript.
- Continue with investigation of climatic factors associated with lightning ignition.
- Collate and analyse data to investigate trends in fuel moisture content and soil dryness during the past 30 years.

Restoring natural riparian vegetation systems along the Warren and Donnelly Rivers

SPP 2013-004

Team members

M Byrne, T Hopley, T Macfarlane, C Ramalho, C Yates

Context

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

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

Aims

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

Summary of progress and main findings

- Collection of leaf and seed material from 12 populations across three climate zones for each of *Callistachys lanceolata* and *Taxandria linearifolia* along the Warren River has been completed.
- Collection of leaf and seed material from 12 populations across four climate zones for *Astartea leptophylla* has been completed.
- Initial analysis of optimisation samples from all three species has been completed and enzymes selected for further genomic analysis.
- DNA has been extracted from the 864 leaf collections, and the DNA sent for genotyping-by-sequencing.
- Climate modelling has been completed for five species under current and future climate change scenarios.

Management Implications

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

establishment of biodiverse plantings that maximise ecological function for enhanced persistence and resilience. Development of a strategic revegetation program for the riparian areas of the Warren and Donnelly catchments will provide an integrated approach to habitat restoration that promotes improved plant community function and improves the knowledge and capacity of restoration practitioners and land managers.

Future directions (next 12 to 18 months)

- Analysis of genomic data from genotyping-by-sequencing results to determine genetic adaptation between populations and climate zones for three species.
- Undertake experimental plantings of seed collected from populations across the climate gradient.
- Sample from experimental plantings to send for genomic analysis to assess establishment and performance to determine any effects of adaptation to drier environments on current performance of germplasm in revegetation projects.

Responses of terrestrial vertebrates to timber harvesting in the jarrah forest

SPP 2012-038

Team members

A Wayne, C Ward, C Vellios, M Maxwell

Context

Understanding the impacts of timber harvesting on the terrestrial vertebrates of the jarrah forest is necessary for biodiversity conservation and development of ecologically sustainable forest management. This work is part of the Kingston Project and a complement to the FORESTCHECK monitoring program.

Aims

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

Summary of progress and main findings

- Spotlight monitoring on three standardised transects was maintained at six repeat surveys per transect per year. Ngwayir (western ringtail possum) populations in the greater Kingston area declined to almost undetectable levels between 1998 and 2001. One or two individuals have been detected in 2006, 2012 and 2013. Previously an average of 10-12 individuals (up to 33) were detected per transect per night. Koomal (brushtail possum) average detection rates have approximately halved since a peak in 2005.
- A review of all available spotlight monitoring data indicates that the ngwayir has declined to almost undetectable levels across the upper Warren area. The ngwayir population in the upper Warren was the largest known population, is genetically distinct, and had higher genetic diversity than Bunbury and Busselton populations.
- Data from previous trapping and spotlighting has been collated and validated. Analyses and preparation for publication are underway, beginning with medium-sized mammal responses to timber harvesting.
- Data from this study has been a primary source of evidence that indicates that five species have now declined in succession over a 10 year period in the upper Warren area (dunnart, wambenger, quenda, ngwayir and woylie), to similar extents (>90%), at similar rates and with no sign of significant or sustained recovery.

Management Implications

- Information on the impacts of timber harvesting on terrestrial vertebrates will lead to improved, ecologically sustainable forest management practices and the conservation of biodiversity.
- The serial decline of multiple species of marsupial in the upper Warren area, of which the ngwayir is one (the others being dunnart, wambenger, quenda, and woylie) is of serious concern requiring action, especially given the high conservation value of the area and the importance of the populations it supports including the species already mentioned and others such as the numbat, tammar wallaby and chuditch.

Future directions (next 12 to 18 months)

- Publish findings of immediate and short-term responses of medium-sized mammals to jarrah forest timber harvesting, based on trapping and spotlight monitoring data.

Fire behavior and fuel dynamics in coastal shrublands

SPP 2012-036

Team members

K Knox, L McCaw

Context

Shrubland ecosystems are widespread in south-western Australia and are the predominant vegetation type in coastal areas between Geraldton and Esperance. Coastal shrublands are renowned for their flammability, and fires can be fast-moving and intense when dead fine fuels are dry and wind speeds exceed 15 km h^{-1} . Fires may transition abruptly from the litter layer to the shrub layer in response to minor changes in wind speed and fuel dryness, making it difficult to use prescribed fire reliably to meet management objectives. Currently the Department does not have a fire behaviour prediction guide specific to coastal shrublands, and this represents a significant gap in science-based decision making to underpin the use of fire for bushfire risk management and biodiversity conservation. This issue was highlighted by the Special Inquiry into the November 2011 Margaret River bushfire conducted by the Hon. Mick Keelty. This project addresses Recommendation 4 of the Keelty Special Inquiry that the Department be supported to conduct further research into the fuel management of coastal heath in the south-west of Western Australia exploring alternatives to burning as well as best practice for burning.

Aims

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

Summary of progress and main findings

- A pilot study was undertaken at seven sites to test the cost-effectiveness and practicality of different fuel sampling techniques.
- Four sites suitable for collecting fire behaviour data have been established within planned burn areas in Albany, Frankland, Perth Hills and Moora districts.
- Data from fires in Western Australian shrublands have been included in a fire spread model developed collaboratively by researchers from Australia, New Zealand and Mediterranean Europe.

Management Implications

- Development of a systematic approach to describing fuels and predicting fire behaviour in coastal shrublands will allow the Department to better implement its fire management program.
- Improved knowledge of factors determining fire behaviour in shrublands will contribute to more effective training programs for fire managers and fire-fighters from the Department and other organisations.

Future directions (next 12 to 18 months)

- Collect fire behaviour from planned burns as these are implemented.
- Plan and conduct further experimental burning to quantify threshold conditions for sustained fire spread in shrublands of different structure and time since fire.
- Evaluate and verify the performance of the collaboratively-developed fire spread model for Western Australian shrublands.

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

SPP 2012-029

Team members

N Burrows, B Ward

Context

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

Aims

- Understand and quantify the long-term effects of various fire regimes on the floristic composition of jarrah forests.
- Determine the long-term effects of various fire regimes on tree health and growth rate.

Summary of progress and main findings

- Floristic assessments have been completed at all sites.
- Tree measurements were completed at the McCorkhill site.
- Data are being prepared for analysis and write-up.
- Burn treatments have been implemented according to schedule, with autumn burning undertaken at Perup in April 2014.

Management Implications

Tree growth data show that fire treatments have had no significant effect on tree mortality and growth. Further data analysis is required to assess the long term effects of fire on floristic composition and richness.

Future directions (next 12 to 18 months)

- Continue fire treatments - the value of this project is that it is designed as a long-term investigation of fire regimes.
- Prepare, analyse and report on data collected since 1986, and prepare a scientific paper for publication.

North Kimberley Landscape Conservation Initiative: monitoring and evaluation

SPP 2012-027

Team members

I Radford, R Fairman

Context

This project is a biodiversity monitoring and evaluation program to inform adaptive management of fire and cattle in the north Kimberley. The adaptive management program that forms the Landscape

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

Aims

- Inform management of biodiversity status in representative areas after prescribed burning and cattle control programs have been applied.
- Provide warning when landscape ecological thresholds have been reached, for example decline of mammals to below 2% capture rate, or decline of mean shrub projected ground cover to <2%.
- Compare biodiversity outcomes in intensively managed and unmanaged areas so that the effectiveness of management interventions in maintaining and improving conservation values can be evaluated.

Summary of progress and main findings

- This project is now into its 4th year of monitoring in the North Kimberley and a total of 86 sites have been surveyed for mammals and vegetation structure, and 101 sites for vegetation alone. Ten rainforest sites have been surveyed at least once. Twenty five sites at the Mitchell Plateau have been surveyed over four consecutive years. Sites at King Leopold Range National Park have been surveyed three times, Prince Regent twice and Bachsten Creek, Drysdale River and Mt Elizabeth once.
- Data from monitoring sites, combined with GIS data layers, confirm that mammal distribution patterns are strongly influenced by vegetation cover, cattle impacts and fire regime particularly the frequency of late dry season fires.
- An inverse relationship between the amount of surrounding country burnt, ground layer vegetation cover and mammal abundance confirms the importance of prescribed burning to conserve vegetation cover needed by mammals.
- Late season fires can have detrimental effects on structures that mammals need in the environment including large hollow bearing trees and fallen timber. Burning early in the dry season acts to protect vegetation structures needed by mammals.
- At the regional scale monitoring shows that most Kimberley mammal species recorded historically are still present and that abundance and richness values are well above threshold values seen in the Northern Territory where mammal populations have collapsed. Mitchell Plateau, Prince Regent and Bachsten Creek have the highest mammal abundance and richness, King Leopold Range intermediate, and King Edward River, Drysdale River and Mount Elizabeth had the lowest mammal abundance/richness and are of greatest conservation concern.
- Mammal abundance and richness has increased at the Mitchell Plateau compared with earlier surveys by the Department from 1994 to 2010. Mammal species have recolonised habitats and become more abundant with implementation of LCI initiatives since 2008, including greater use of planned burning early in the dry season and introduction of a cattle culling program.
- The monitoring program has recorded most of the mammal species that would be expected at the regional scale. Exceptions are the black-footed tree rat (presumed extinct), the brush tailed phascogale (recently sighted at Mitchell Plateau but not recorded in surveys), the nabalek rock wallaby (only confirmed on off-shore Kimberley Islands) and the rock ringtail possum (not recorded in monitoring but reported elsewhere in the region).
- New projects are being initiated to further investigate the status of species unaccounted for during the monitoring program. This includes a nest box installation project to monitor specialist arboreal species and a collaborative PhD project with the University of Melbourne on tree hollow distribution and limitation of arboreal mammals.

Management Implications

- There is strong evidence that cattle have negative influences on critical weight range mammals, including threatened species such as *Conilurus penicillatus*. Culling programs should therefore be maintained and expanded in important conservation reserves.
- There is now statistical evidence that the LCI has shifted the fire regime in the north Kimberley from dominance by late dry season bushfires to a situation where equal proportions of the country are burnt during the early and later periods of the dry season. Monitoring and evaluation data suggest that this is benefitting threatened mammal assemblages, or at least is not detrimental to them, and provides evidence that current fire management practices in the north Kimberley should be continued to maintain conservation values in the region.
- Lower mammal abundance and diversity at inland sites in conjunction with higher cattle and fire frequency indicates that prescribed burning and cattle culling initiatives should be expanded into these areas as a matter of priority.
- Dingoes can contribute to the conservation of small mammals by suppressing cats, and therefore dingo baiting should be avoided in conservation reserves.

Future directions (next 12 to 18 months)

- Monitoring and evaluation will continue so that the effectiveness of management interventions can be evaluated in the longer term.
- Data collected during the initial three years of the monitoring program will be analysed and published.
- Collaborative monitoring programs will be expanded to incorporate adjoining areas on pastoral lease and indigenous-owned land to provide comparative data on mammal populations and vegetation condition where cattle populations remain high and fire regimes are not managed.

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

SPP 2012-002

Team members

M Byrne, C Yates, B Macdonald, L McLean, Dr S Prober (CSIRO), Prof W Stock (Edith Cowan University), Prof B Potts (University of Tasmania), A/Prof R Vaillancourt (University of Tasmania), Dr D Steane (University of Tasmania)

Context

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

Aims

The project will test the following alternative hypotheses:

- Widespread species, having evolved under highly variable environments, retain high potential for adaptability to environmental change within the gene pool of local populations or individuals (implying that genetic material sourced from local populations will have tolerance to changing climatic conditions).

- Widespread species, having evolved across wide ecological gradients, comprise a suite of locally adapted sub-populations (implying that genetic material should be sourced not from local populations but from distant and potentially resilient populations that are pre-adapted to the future climate).

Summary of progress and main findings

- Genetic and ecophysiological analysis were undertaken in nine populations across climate gradients in *Eucalyptus salubris* (Western Australia) and *E. tricarpa* (Victoria).
- The *E. tricarpa* common-garden data revealed high plasticity in most of the measured functional traits, particularly in water use efficiency and leaf density. In *E. salubris*, most functional traits showed little variation across the climate gradient, in particular leaf morphology appeared not to respond to climate in this study. Water use efficiency appeared highly plastic in both species, meaning that individuals are able to adjust to drier or wetter conditions.
- Both species showed genetic differences, indicating genetic variation among populations across the gradient, and outlier analysis identified 58 (*E. tricarpa*) and 94 (*E. salubris*) loci with significantly greater differentiation, indicating adaptation.
- In both species, particular genetic markers were correlated with climatic variables, and some were also correlated with functional traits, including plasticity of particular traits. This provides further evidence that particular regions of the genome relating to functional responses may be under selection in relation to climate. Markers potentially responsible for climate adaptation appear to be common to both species, suggesting that some mechanisms of climate adaptation might be conserved across species.
- Two papers describing the ecophysiological and genetic responses were published in *Plant Cell and Environment* and *Molecular Ecology*.

Management Implications

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

Future directions (next 12 to 18 months)

Complete additional analysis on *E. salubris* and write scientific papers.

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

SPP 2011-020

Team members

L McCaw, R Robinson, B Ward

Context

This project provides information to underpin the management of karri in the immature stage of stand development (25-120 years old). Regenerated karri stands have important values for future timber production, biodiversity conservation and as a store of terrestrial carbon. Immature stands regenerated following timber harvesting and bushfire comprise more than 50,000 hectares and represent around one third of the area of karri forest managed by the department. 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 in the karri forest, and have been measured repeatedly over a period of several decades, providing important information to support and improve management practices. This project addresses emerging issues likely to be of growing importance in the next decade, 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.

Aims

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

Summary of progress and main findings

- Findings from the Warren block thinning experiment were reported in a book on long term ecological monitoring studies in Australia (*Biodiversity and environmental change*: CSIRO Publishing, February 2014).

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.
- Tree mortality associated with *Armillaria* root disease appears to reduce in older stands, and small gaps created by dead trees become less obvious as stands mature. Localised tree mortality can be regarded as a natural process and is likely to contribute to patchiness in the mature forest. However, the extent of tree mortality in silviculturally managed stands should be monitored to ensure that stand productivity and other forest values remain within acceptable ranges.

Future directions (next 12 to 18 months)

- Analyse and report on trends in tree and stand growth, with a focus on possible links between climate and growth.
- Analyse trends in the incidence and severity of *Armillaria* root disease at Warren block since 2000.
- Develop a plan for a second thinning at Warren block.

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

SPP 2011-019

Team members

J Farr, A Wills, P Van Heurck

Context

Within the history of forest and natural landscape management in Western Australia, many invertebrates are known to utilise forest biomass for their survival and in doing so impart some form of damage to leaves, shoot, roots, stems or branches. There are 10 recognised invertebrate species with demonstrated significant impact on tree health, vitality and timber quality within our natural environment. Currently the most prevalent insect pests of concern in native forests are *Perthida glyphopa* (jarrah leafminer, JLM), *Phoracantha acanthocera* (bullseye borer, formerly known as *Tryphocaria acanthocera* BEB) and *Uraba lugens* (gumleaf skeletoniser, GLS). Both JLM and GLS have documented population outbreak periods, and BEB incidence appears to be responsive to drought stress and is likely to increase. However, Western Australian forests and woodlands also have a history of developing unexpected insect outbreaks with dramatic consequences for the ecosystem health and vitality. The decline in mean annual rainfall in south-west Western Australia since the 1970s and global climate model predictions of a warmer and drier environment mean conditions for invertebrate pests will alter significantly in the next decade as our environment shifts toward a new climatic regime. This project addresses both recognised and emerging/potential invertebrate forest pests, and is designed to augment forest health surveillance and management requirements by providing knowledge on the biological aspects of forest health threats from invertebrates in the south-west of Western Australia.

Aims

- Investigate aspects of pest organism biology, host requirements, pathology and environmental conditions (including climatic conditions) that influence populations.

- Determine distribution of the invertebrate pests, including outbreak boundaries and advancing outbreak fronts, using aerial mapping, remote sensing and road surveys.
- Measure relative abundance of invertebrate pests, including quantitative population surveys and host/environmental impact studies where appropriate and/or possible.
- Utilise appropriate monitoring technologies including GIS and remote sensing.
- Liaise with land managers and the community regarding responses to pest insect outbreaks.

Summary of progress and main findings

- Pheromone trapping of GLS was used to quantify the 2013/14 GLS population level.
- More than 250,000 ha of forest was defoliated by GLS in 2010/2011. GLS populations have since decreased from this peak. GLS population changes indicate density dependent mortality is operating in this population decline. The mechanism of density dependent mortality is not yet understood.
- A report summarising results of GLS monitoring 2010–2014 has been drafted.
- The relationship between November and January populations of GLS larvae was investigated to allow integration of historical and current monitoring data.

Management Implications

- Pheromone trapping is effective in monitoring GLS populations and could be used routinely to identify the likelihood of GLS outbreak. Moth populations are a good predictor of subsequent larval populations and may provide early warning of outbreak events.
- Integration of GLS population and impact data from two major outbreak events will facilitate analysis of links between climatic factors and outbreak development. Preliminary analysis indicates a strong coupling between GLS outbreak and periods of below-normal rainfall at annual or longer timescales.

Future directions (next 12 to 18 months)

- Refine relationship between moths captures and Normalized Difference Vegetation Index to investigate the spatial structure of the onset and development of GLS outbreaks.
- Further develop the relationship between defoliation rates, leaf area index and satellite imagery.
- Investigate the role of rainfall fluctuation in initiating GLS outbreaks.

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

SPP 2011-011

Team members

C Yates, M Byrne, S Tapper, A/Prof G Wardell-Johnson (Curtin University), Prof L Mucina (The University of Western Australia), A/Prof K van Niel (The University of Western Australia), Prof SD Hopper (The University of Western Australia), Prof S Franklin (University of Saskatchewan)

Context

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

Aims

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

Summary of progress and main findings

- Continued integration of plant species records from the floristic survey of 450 plots with environmental measurements of the 15 GOs in database.
- Published paper in the journal *PLOS-ONE* describing the utility of LiDAR and other multispectral remotely sensed data for identifying refugia, confirming that GOs will provide refugial opportunities for species under the influence of a drying climate.
- Published paper on phylogeographic patterns in *Kunzea pulchella* in the journal *Diversity and Distributions* and *Stypandra glauca* in the *Journal of Biogeography* confirming that GOs have provided refugial opportunities for species during previous cycles of climate change.

Management Implications

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

Future directions (next 12 to 18 months)

- Complete the integration of plant species records from 450 plots across 15 GOs in a database.
- Model the influence of climate, microclimate and soil depth on GO plant community composition.
- Write journal papers on ecological evidence for granite outcrops as historical and future climate change refugia.

Fire regimes and impacts in transitional woodlands and shrublands

SPP 2010-011

Team members

C Yates, C Gosper, Dr S Prober (CSIRO), G Wiehl (CSIRO)

Context

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

for mallee and mallee-heath communities in the GWW, but similar information for the dominant eucalypt woodlands is urgently 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.
- Investigate the effects of time since fire on the assembly and recovery of gimlet woodlands, including on plant and animal community composition and development of ecosystem structure.
- Measure fuel and carbon dynamics with time since fire in gimlet woodland.
- Investigate pathways to weed invasion in the GWW.

Summary of progress and main findings

- A multi-century time since fire chronosequence of 76 plots has been established in gimlet woodlands.
- A paper describing vegetation structure changes across the chronosequence has been published in *Forest Ecology and Management* and an Information Sheet produced.
- A paper arising from Vesta visual fuel assessments across the chronosequence has been published in the *International Journal of Wildland Fire*.
- A combination of species- and asset-led approaches have been used to identify alien plant threats. The species-led approach identified aliens likely to be increasingly problematic in a changing climate. The asset-protection approach used systematic flora survey data to identify key pathways to alien invasion.
- In collaboration with CSIRO Ecosystem Sciences, changes in ant communities across 51 sites of the gimlet chronosequence have been assessed. Ant functional groups changed in abundance with time since fire in a manner consistent with predictions based on how previously-documented changes in vegetation structure, such as in insolation and litter cover, would affect habitat suitability for ants.

Management Implications

- Changes in vegetation structure, cover and hazard across the chronosequence indicate maximum community flammability at intermediate times since fire, conflicting with the common assumption that fuel availability increases monotonically with time since fire and hence supporting the revision of fire behaviour ratings for eucalypt woodlands in the GWW.
- Fires initiate a succession process leading to the replacement of mature woodlands with intermediate time-since-fire woodlands with greater cover and connectivity of key fuel layers, which likely instigates a self-reinforcing fire regime shift favouring larger and/or more uniform fires that would lead to substantial losses in conservation values of *E. salubris* woodlands. Following recent large wildfires, regenerating woodlands will be passing into the more flammable intermediate time-since-fire stage over coming decades, creating increasing challenges for fire management.
- Strong correlations between visual fuel assessments and detailed quantitative measurements indicate that visual assessments can usefully assess changes in fuels in GWW woodlands. As visual assessments can be completed more rapidly than alternative methods, this research assists managers improve the efficiency of fuel measurement.
- A limited range of alien plants (12% of total taxa) in the GWW are predicted to be both highly invasive in the future and feasibly eradicated or contained, and it is these species that should be subject to species-led management efforts (e.g. *Acetosa vesicaria*, *Cenchrus ciliaris*).
- A consistent set of management-related predictors of alien presence were identified, including closer proximity to towns, buildings and water points, and occurrence on a geology and soil type associated with prospective mineral deposits. Management recommendations to reduce rates of alien plant spread and/or improving the detection of alien plant populations include: targeting abandoned and current settlements for survey and localised removal of disjunct alien plant populations; minimising where possible new settlement and water point creation in

locations currently remote from these features; and closure of water points on conservation estate.

Future directions (next 12 to 18 months)

- Add new material to NatureMap on vegetation composition change with time since fire across the gimlet chronosequence.
- Complete manuscript preparation on alien plant threats in the GWW and ant community changes across the gimlet chronosequence.
- Refine models estimating the time since fire of long-unburnt gimlet woodlands through measurement of growth increments of different gimlet size classes.
- Commence measurement of carbon pools across the gimlet chronosequence to determine the role of fire management in carbon sequestration.
- Use genomics technology to investigate changes in soil microbial communities across the gimlet chronosequence.

Aspects of dieback behaviour relevant to the formulation of jarrah silviculture guidelines

SPP 2007-009

Team members

M Stukely

Context

Jarrah stands are managed in accordance with *Sustainable Forest Management Guideline No.1: Silvicultural Practice in the Jarrah Forest*, to promote the growth of crop trees for timber production and to conserve other forest values. The presence of the pathogen *Phytophthora cinnamomi* requires implementation of appropriate measures to minimise the impact of *Phytophthora* dieback disease on the forest and the consequent reduction in its productivity and ecological integrity. On sites where disease impact is predicted to be moderate to high, the silvicultural operation termed 'Selective cut in dieback' is in general use. A number of key assumptions underpin this guideline.

Aims

- Understand the effect of current silvicultural treatments on dieback expression.
- Understand the effect of alternative approaches to silvicultural treatment on dieback expression.
- Investigate the effect of retained overstorey in relation to dieback impact escalation.
- Investigate the occurrence and persistence of jarrah regeneration (and key tolerant species) in the presence of *P. cinnamomi* on different sites.

Summary of progress and main findings

- Measurement of overstorey and mid-storey trees has been completed at six sites in Cobiac block near Jarrahdale that represent different combinations of thinning intensity, dieback status and topographic position.
- Measurement of overstorey and mid-storey trees has been completed at two sites established in Gordon block in adjacent areas of dieback-affected and dieback-free forest to represent the silvicultural treatment of selective cut in dieback with herbicide thinning to a stand basal area of 15 m ha⁻².
- Permanent back-up tagging of trees has been undertaken to facilitate long-term monitoring.
- Hemispherical digital photography has been undertaken to quantify canopy condition at each site as a basis for monitoring change over time.
- Dieback disease fronts adjacent to all sites have been mapped by trained dieback interpreters and permanently marked to allow monitoring of disease spread upslope, downslope and across slope under different stand conditions.

Management Implications

- The project provides scientific data and conclusions to evaluate key assumptions that underpin *SFM Guideline No.1*. The findings are relevant primarily to jarrah forest areas that are managed for timber production in the presence of *Phytophthora* dieback, and some key elements also apply to management for nature conservation values.
- Knowledge gained will be used to support, modify and update the guideline. The project will contribute to the provision of a clearer scientific basis for the adaptive management of jarrah forest in the presence of *Phytophthora* dieback. Long-term detailed monitoring will be possible.

Future directions (next 12 to 18 months)

This project will be continued by Forest and Ecosystem Management Division staff with assistance in data analysis as required.

Fire regimes and biodiversity decline in the Kimberley test

SPP 2007-008

Team members

I Radford, R Fairman

Context

Recent studies have shown declines in some elements of biodiversity across northern Australian savannas. Biodiversity declines in otherwise intact landscapes have been attributed to increased intensity and frequency of fires. Studies in central Australian arid environments have highlighted the strong influence of fire, combined with introduced predators, on fauna abundance. This evidence from both the tropical savannas and arid environments has implications for northern Western Australia, including the Kimberley, where there have been major shifts in fire regimes. A direct link between abundance of threatened animals and fire regimes in the Kimberley has yet to be established. This study will establish whether fire has a strong influence on abundance of savanna fauna in the north and east Kimberley. It will address the question of how fire regimes influence critical weight range mammals, reptiles, frogs and invertebrates by analysing vegetation structure and resource dynamics in association with changes in abundance.

Aims

- Spatially quantify the fire history of the Mitchell River and Purnululu regions.
- Establish whether fire history influences the abundance of threatened groups, particularly mammals, and quantify recolonisation rates for threatened species after fire.
- Link fire history and mammal abundance with vegetation and resource community (consumers including invertebrates and small vertebrates) that might explain the effect of fire.

Summary of progress and main findings

- Research under this project was completed with the publication of papers on the role of *Callitris* patches as habitat in savannas, and on the conservation status of ants in the northern Kimberley.

Management Implications

Persistence of critical weight range mammals will be favoured by fire mosaics with small burn patch size and retention of long-unburnt patches of vegetation across the savanna landscape. While this may be difficult to achieve at a regional scale due to resource constraints, target management areas could be established for the application of local, fine-grain mosaics to test for their conservation benefits. Evaluating biodiversity outcomes of the Department's fire management operations is crucial within an adaptive management context to avoid the mammal community collapses that have occurred elsewhere in northern Australia.

Future directions (next 12 to 18 months)

This project is now complete.

Identification of seed collection zones for rehabilitation

SPP 2006-008

Team members

M Byrne, D Coates, S McArthur

Context

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

Aims

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

Summary of progress and main findings

- A paper on population genetic structure and phylogeographic patterns in *Kennedia coccinea* has been drafted and seed sourcing guidelines are being developed.
- Analysis of microsatellite variation in *Allocasuarina humilis* is underway.
- Twenty eight populations of *Banksia sessilis* have been genotyped and data analysis has commenced.
- Collections from 24 populations of marri (*Corymbia calophylla*) have been made throughout the species range and DNA extraction has been completed.
- Microsatellite loci for marri are being developed.

Management Implications

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

Future directions (next 12 to 18 months)

- Complete publication of papers on genetic analysis of phylogeographic patterns and genetic structure, and seed sourcing strategies for *K. coccinea* and *A. humilis*.
- Complete analysis of genetic structure in *B. sessilis* and *C. calophylla* and prepare publications.

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

SPP 2006-003

Team members

R Robinson, L McCaw, J Farr, K Whitford, R Cranfield, G Liddelow, V Tunsell, B Ward, A Wills, P Van Heurck

Context

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

Aims

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

Summary of progress and main findings

- Monitoring of macrofungi, cryptogams, terrestrial vertebrates, birds and invertebrates and measurements of forest structure and litter layer were completed on nine grids in Donnelly District during winter/spring of 2013.
- A draft of the 2013 Annual Report (Donnelly) has been compiled.
- Seven new monitoring grids were installed in Blackwood District and two in Perth Hills District.
- Measurements of coarse woody debris and monitoring of terrestrial vertebrates, birds and invertebrates was conducted on the Blackwood and Dwellingup grids in autumn 2014.
- Analysis of data from the 10-year monitoring period (2002–2012) is progressing.
- The project was featured in a book on long term ecological monitoring studies in Australia (*Biodiversity and environmental change*: CSIRO Publishing, February 2014).

Management Implications

FORESTCHECK provides a systematic framework for evaluating the effects of current silvicultural practices across a range of forest types and provides a sound basis for adaptive management.

Future directions (next 12 to 18 months)

- Determine directions for future monitoring from 2015 and beyond.
- Continue analysis of data from the 10-year monitoring period (2002–2012) and preparation of draft manuscripts for publication of 10-year results.
- Undertake spring monitoring of Blackwood and Perth Hills District grids.
- Analyse 2014 data and prepare 2014 Annual Report.

Monitoring stream biodiversity (KPI 20 of the Forest Management Plan)

SPP 2006-002

Team members

M Pennifold, A Pinder, K J Williams

Context

The Forest Management Plan 2004–2013 included a range of key performance indicators (KPIs) based on the internationally agreed Montreal Protocols. KPI 20 is the percentage of water bodies (e.g. stream kilometres, lake hectares) with significant variance of biodiversity from the historic range of variability. This project addressed this KPI by monitoring aquatic invertebrates in representative stream sites within the jarrah and karri forests of south-western Australia, particularly in relation to forest management practices.

Aims

- Assess aquatic invertebrate diversity in representative jarrah and karri forest streams against reference condition by comparing the family richness of sampled invertebrates to richness predicted by a previously constructed model (AusRivAS) developed using data from 'minimally disturbed' reference sites in the same regions.
- Examine relationships between species richness and degree of catchment disturbance (burning and harvesting) for selected invertebrate groups.

Summary of progress and main findings

- Invertebrates from the 2013 round of sampling were identified.
- An article was written for *LANDSCOPE* magazine, 'Saving streams of the south-west forest'.
- Biogeographic patterning of aquatic invertebrates in south-west forest streams was analysed in collaboration with scientists from CSIRO in Canberra, and a journal article is being prepared.

Management Implications

The *Forest Management Plan 2004–2013* target of no stream sites with fauna significantly different to reference condition was not achieved. However, stream sites with greatest divergence in diversity from reference condition were generally in the drier parts of the northern and eastern jarrah forest or were naturally saline or acidic. Part of the reason for these sites being apparently impaired was that the AusRivAS models were produced with few reference sites in such streams, so the model is likely to have overestimated richness. However, a few stream sites were not in these categories and require further monitoring and investigation to examine the cause of the reduced diversity. There was very little evidence that the proportion of the catchment burned and/or harvested affected any of the stream invertebrate biodiversity measures or overall community composition.

Future directions (next 12 to 18 months)

- Re-sample streams in 2015, with a focus on those considered to be in minimally disturbed catchments, to provide long-term data on the response of aquatic invertebrate communities to declining rainfall.
- Continue to update fire and logging history for catchment areas.
- Complete and publish a paper on biogeographic patterning of aquatic invertebrate communities in south-west forest streams.
- Publish further papers examining impacts of declining rainfall and forest management practices on macroinvertebrate diversity in forest streams.
- Publish report with summaries of 8 year trends (2005 to 2013) for all monitoring sites.

Monitoring post-fire effects from the 2001 Nuyts wildfire

SPP 2006-001

Team members

G Liddelow, B Ward, R Cranfield, P Van Heurck, L McCaw, Frankland District Staff

Context

Understanding the effects of different fire regimes is important for developing and implementing ecologically appropriate fire regimes and for managing fire for the protection of life and property. This study was established to take advantage of the opportunity presented by an unplanned fire that was ignited by lightning in March 2001 following an extended period of below-average rainfall.

Aims

Monitor the impact of severe bushfire on plants, invertebrates, vertebrate fauna and stand structure in karri/tingle forest.

Summary of progress and main findings

A manuscript reporting on recovery of overstorey and mid-storey trees and eucalypt regeneration has been submitted to *Australian Forestry* and is being revised following peer review.

Management Implications

- This study contributes to the development of ecologically appropriate fire regimes for tall forests in southern Western Australia. Results to date indicate that long-term fire exclusion can result in very severe fire impacts on many components of the forest ecosystem and that large-scale, high-intensity bushfires can have undesirable ecological outcomes, including simplification of plant population structure and depletion of seed banks.
- Information provided by this project is being used to plan the reintroduction of prescribed fire into the area burnt by the 2001 bushfire.

Future directions (next 12 to 18 months)

- Revised manuscript on tree recovery and seedling regeneration to be submitted for final publication.
- Bird survey data will be written up as a short communication.

Burning for biodiversity: Walpole fine-grain mosaic burning trial

SPP 2004-004

Team members

N Burrows, J Farr, R Robinson, G Liddelow, B Ward, R Cranfield, V Tunsell, P Van Heurck, A Wills, Frankland District Staff

Context

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

Aims

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

Summary of progress and main findings

- Field work is almost complete. Data have been compiled, collections sorted and documented, and data analysis commenced.
- Visiting scientist Professor Scott Stephens, University of California, Berkeley, has commenced analysis of mosaic fire patterns in the landscape using data from London forest.

Management Implications

The study demonstrates that fine-grain patch-burning is operationally feasible in forest areas. Benefits to biodiversity at the landscape scale, especially invertebrates and fungi, are increasingly evident. Any benefits to higher order organisms may take longer to emerge.

Future directions (next 12 to 18 months)

- Targeted field sampling of invertebrates and fungi to fill data gaps in the mosaic spectrum.

- Complete data analysis and write papers.

Management of environmental risk in perennial land use systems

SPP 2004-003

Team members

M Byrne, C Munday, K Bettink, J Sampson, M Millar

Context

The development of perennial-based land use systems for management of dryland salinity and to increase the productivity of agricultural systems promises significant environmental and economic benefits, but there are also risks to existing natural biodiversity. These risks include the establishment of plant species in new locations where they may become environmental weeds and the possible gene flow from cultivated populations into natural populations with the potential for hybridisation with native species. Both of these may result in a loss of biodiversity from natural environments. Risk assessment systems can be used to inform selection and management of agriculturally useful species to minimise the risk to natural environments.

Aims

- Develop and implement procedures for the management of environmental risk in the form of assessment and management protocols to be applied to all germplasm under research and development within the Future Farm Industries Cooperative Research Centre (FFI CRC).
- Disseminate information about these processes to a wide audience of researchers, land managers and the community via FFI CRC publications, national weed risk forums and conferences.
- Publish weed and genetic risk assessment protocols and provide advice to encourage adoption of risk assessment procedures within and outside the FFI CRC.

Summary of progress and main findings

- An information sheet on weed risk and the FFI CRC assessment protocol has been completed and published on the FFI CRC website.
- New weed risk assessments have been completed for native forage species that may be used outside their natural range and these have been published online on the FFI CRC website.
- A paper describing the FFI CRC environmental risk strategy for minimising the risk to the environment from agriculturally useful species was presented at the 5th Victorian Weeds Conference in Geelong, Victoria. The audience represented a wide range of organisations engaged in the control of environmental weeds from policy development to identification, monitoring and on-ground control.
- The concepts of weed and genetic risk have continued to be promoted in FFI CRC publications and raised in forums with stakeholders in Western Australia and nationally.
- An environmental risk strategy and framework was developed for the FFI CRC. All the components have been published, promoted and implemented. Assessments and other material prepared within this project are published on the Department of Parks and Wildlife website.
- The weed risk assessment protocol, genetic risk assessment protocols, species management guides and field trial guideline have been prepared and published for some species promoted by the FFI CRC to inform management to minimise the risk to natural environments.
- The environmental risk strategy, framework and its components have been promoted widely and a weed risk note provided for a publication on tropical grasses published by the FFI CRC.

Management Implications

- Promotion of the concepts of weed and genetic risk management both within and outside the FFI CRC and the development and use of appropriate assessment techniques will reduce the

risk of large-scale plantings of new perennial species introduced from outside Australia, native species used outside their natural range or newly developed cultivars becoming environmental weeds.

- Adoption of the genetic risk assessment process will enable the risk of genetic contamination and hybridisation to be assessed on a site-specific basis. This will help in the development and implementation of processes to manage these risks. The information may also indicate where further research is needed to understand gene flow in the environment. Guidelines and risk assessment will inform species selection and trial and planting plans to minimise the risk of agriculturally useful species to native environments during research, breeding and production system development.

Future directions (next 12 to 18 months)

- The project has been completed with the end of the FFI CRC.

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

SPP 2003-004

Team members

N Burrows, G Liddelow, D Algar, N Hamilton, M Onus, B Ward, Goldfields Regional Staff, Prof T Bragg (University of Nebraska, Omaha)

Context

Despite the relatively pristine nature of most of the arid interior (desert bioregions) and rangelands (beyond the pastoral zone), there has been an alarming and recent loss of mammal fauna, with about 90% of medium-size mammals and 33% of all mammals either becoming extinct or suffering massive range contractions. There is also evidence of degradation of some floristic communities due to altered fires regimes. The extent and nature of change in other components of the biodiversity, including extant mammals, birds, reptiles and invertebrates is unknown. The most likely causes of the decline and degradation in biodiversity are introduced predators, especially the fox (*Vulpes vulpes*) and the feral cat (*Felis catus*), and altered fire regimes since the departure from traditional Aboriginal burning practices over much of the region. Taking an adaptive experimental management approach in partnership with Goldfields Region, this project aims to reconstruct some assemblages of the original native mammal fauna on Lorna Glen, a pastoral lease acquired by the Department. This will be achieved by an integrated approach to controlling introduced predators and herbivores, ecologically appropriate fire management, and fauna translocations.

Aims

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

Summary of progress and main findings

- Cat, fox and wild dog aerial baiting carried out in July 2013 as part of the Western Shield program was effective with the feral cat population reduced by 62% to a Track Density Index of 7. Five of the seven feral cats that were trapped and radio-collared prior to baiting were killed by the baiting (70% mortality).
- A PhD project to investigate interactions between wild dogs/dingoes and wild cats resulted in some 16 dogs and 21 cats being trapped and fitted with GPS collars. Trail cameras (136) were located across Lorna Glen to collect additional data on the occurrence, distribution, density and activity of wild dogs and cats. The study is testing the hypothesis that there is an inverse relationship between dog and cat density. The management implication is that retaining dingoes could result in a reduction in cats.
- Mulgara (*Dasycercus cristicauda*) population size has remained stable since last year and is still relatively high.
- The fire management plan continued to be implemented, including further installation of fuel-reduced buffers around some fire management cells and some core ignition using aircraft.
- With the assistance of Martu Rangers, 32 mulga trees were mechanically extracted and processed to determine biomass and carbon stocks in mulga as part of a program to determine whether good fire management in these ecosystems can reduce greenhouse gas emissions and increase carbon biosequestration.

Management Implications

- This project is providing insurance populations of threatened arid zone mammals.
- Information will inform guidelines for the proactive management of fire in the arid zone rangelands to reduce the severity (scale and intensity) of wildfires and to provide habitat choice through mosaic burning.
- Guidelines for controlling introduced predators in the arid zone rangelands will reduce this threat to native fauna. Reintroduction and protection of mammals of the arid zone rangelands, other extant fauna, vegetation and other elements of the biota will provide reconstruction of animal and plant assemblages in an arid zone ecosystem.
- A framework and protocol for assessing and reporting trends in ecosystem condition in arid zone rangelands will provide a basis for ecosystem condition monitoring.

Future directions (next 12 to 18 months)

- Assess and report on the effectiveness of wild cat and dog baiting.
- Complete a report on 10 years of biodiversity monitoring at Lorna Glen, and a scientific paper.
- Carry out a biological survey of Earraheedy.
- Survey wild dogs, cats and mulgara on Earraheedy where there has been no introduced predator control, and compare results with Lorna Glen.
- Continue to implement the fire management plan including buffer burning and aerial patch burning.

The impact of wildfire in old growth forest of the Walpole-Nornalup National Park on short-range endemic invertebrates and their forest floor communities

SPP 2003-003

Team members

P Van Heurck, Frankland District Staff

Context

Tall tingle and karri forests contain a high proportion of short-range relict invertebrate species. In March 2001, a wildfire in the Nuyts Wilderness near Walpole provided an opportunity to assess the impact of high-intensity fire on the species composition of invertebrate communities. Species composition was

also compared with relict invertebrate communities in prescribed-burnt and long-unburnt tall forests. Understanding the effects of an intense fire on invertebrate biodiversity is important for developing and implementing ecologically appropriate fire regimes and for managing fire for community protection.

Aims

Describe differences in species composition of arthropod forest-floor communities containing short-range endemic species at forest sites with a variety of fire histories.

Summary of progress and main findings

- Further analysis of beetle morphospecies was undertaken.

Management Implications

- The Nuyts invertebrate collection contains a large proportion of invertebrate species previously undescribed from old-growth forests of the Warren Bioregion. The occurrence of these uncommon or short-range endemic species within a wide range of fire ages provides fire managers with a unique and invaluable record of the fire tolerances of invertebrate species.
- Making high resolution images of arthropods available on a website created by local volunteers has facilitated rapid identification of reference collection morphospecies by both local and international scientists.
- In combination with the Nuyts invertebrate collection, the prodromus of beetle morphospecies collected from the Mt Roe National Park provides a basis for meta-comparison of wildfire impacts on old-growth forest ecosystems and the fire resilience of a major invertebrate assemblage.

Future directions (next 12 to 18 months)

- This project has been terminated.

Landscape and fire management interactions and their effects on distribution of invertebrate biodiversity

SPP 2001-005

Team members

A Wills, J Farr

Context

Understanding the factors controlling the distribution of invertebrates in the jarrah forest landscape is important for ecologically sustainable management. Specialised or fire-sensitive faunas that are restricted to particular geomorphic units are important for developing and implementing ecologically appropriate fire regimes and for managing fire for community protection.

Aims

- Document the effects of topography on the distribution and abundance of invertebrates in the jarrah forest.
- Determine whether landscapes provide natural fire and climatic refuges in the northern jarrah forest.

Summary of progress and main findings

- Field work is complete and data have been validated and prepared for analysis.
- Appropriate software for analysis has been purchased, and staff trained in its use.

Management Implications

The finding of high beta-diversity at small geographical scale (tens to a few hundred metres) within valley geomorphic units expands on the findings of other studies in the jarrah forest that show broad similarity of assemblages (low to medium beta-diversity) at medium geographical scales (up to a few tens of kilometres), and higher beta-diversity at large geographical scales. Low frequency of

occurrence of most species makes it difficult to draw conclusions about the refugial nature of southern aspects, though for some species aspect is an apparently important determinant of local distribution. Greater trapping effort over a longer duration would be required to confirm this hypothesis. Disturbance at any geographical scale within the valleys is likely to have a greater effect on invertebrate species composition than disturbance at such a scale in upland jarrah forest.

Future directions (next 12 to 18 months)

- Analyse the dataset using non-metric multidimensional scaling ordination.
- Write up and publish results in a refereed journal.

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

SPP 2000-003

Team members

J Kinal

Context

This is a long-term experiment established in 1999 to address part of Ministerial Condition 12-3 attached to the *Forest Management Plan 1994–2003*. Ministerial Condition 12-3 states that the Department shall monitor and report on the status and effectiveness of silvicultural measures in the intermediate rainfall zone (900-1100 mm/yr) of the jarrah forest to protect water quality.

Aims

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

Summary of progress and main findings

- Monitoring of groundwater levels, streamflow, stream salinity and stream turbidity continued in the two treated catchments (Yarragil 4X and 6C) and in the control catchment (Wuraming).
- Monitoring of groundwater levels, streamflow, and stream salinity also continued in Yarragil 4L, which was thinned in the mid 1980s to examine the effect of thinning on stream water quality and quantity.
- The mild steel V-notch weir plate in Yarragil 4X was corroded and has been replaced by a stainless steel plate to extend the operational life of the weir for ongoing streamflow monitoring.

Management Implications

- These catchments provide a unique long-term record of the hydrological response of the jarrah forest to climate change and forest management practices.
- Findings from these studies informed the preparation of the *Forest Management Plan 2014-23* in regard to management activities to protect and enhance stream water quality and quantity.
- Monitoring at these catchments contributes to reporting to KPI 10 for the *Forest Management Plan 2014-23* which relates to stream condition and groundwater level within fully forested catchments.

Future directions (next 12 to 18 months)

- Continue monitoring of groundwater levels, streamflow, stream salinity and turbidity and rainfall.
- Re-measure forest density along fixed transects in Yarragil 4X and 6C to determine the forest regeneration response to the timber harvest and silvicultural treatments.
- Re-measure tree growth in Yarragil 4L to determine the long-term hydrological response to thinning, and write a paper.

Evaluation of key soil indicators of sustainability in Australian mediterranean forests (Indicators 4.1d, 4.1e)

SPP 1999-021

Team members

K Whitford

Context

Timber harvesting and forest management activities impact on soil physical and chemical properties. Evaluation of soil physical and chemical status will contribute to the development of standards for soil management during timber harvesting activities in the jarrah and karri forests.

Aims

- Investigate the use of soil organic matter as an indicator of ecologically sustainable forest management and examine the impact of fire on organic C and N in the jarrah and karri forest.
- Provide a scientific basis for the soil disturbance monitoring and management system applied in jarrah and karri forests by establishing baseline data on the intensity and extent of soil disturbance in harvesting coupes, and developing, refining and implementing survey techniques for estimating soil disturbance.
- Develop appropriate techniques for measuring bulk density in gravelly forest soils, and examine the relationship between soil disturbance class, bulk density and soil shear strength.
- Investigate the impact of extraction track compaction on tree and stand growth in the karri forest.

Summary of progress and main findings

- Commenced a review of the long-transect soil survey technique which was adopted based on findings from this project.

Management Implications

- Engineering solutions, such as covering the ground with harvest waste prior to harvesting, can provide small reductions in soil compaction and disturbance; however, on most forest soils, operating machinery in dry conditions and thoughtful planning and management of machine movement across the harvested area offer the simplest solutions for minimising the impact of timber harvesting on soils.
- This work contributed to development and implementation of Appendix 6 of the *Forest Management Plan 2004–2013*, the *Manual of Procedures for the Management of Soils Associated With Timber Harvesting in Native Forests* and the *Soil and Water Conservation Guideline*. The principles of soil disturbance management identified in this project continue to be used to manage the condition of soils subject to timber harvesting.

Future directions (next 12 to 18 months)

Finalise publication of findings on soil carbon, and complete the review of the long-transect survey technique.

State Salinity Strategy wetland monitoring

SPP 1998-018

Team members

A Pinder, D Cale, M Lyons, C McCormick, J Lane, K Quinlan, A Clarke, Y Winchcombe, RJ Shiels (University of Adelaide)

Context

Substantial biodiversity has been lost across the Wheatbelt Region of Western Australia over the past 100 years. The most pronounced physical changes to wetlands have been associated with native

vegetation clearing and salinisation. Broad-scale clearing has more or less ceased but salinisation and fragmentation processes will continue to be expressed for many decades. While it is known that salinisation is a major threat to wetland biodiversity, the relationships between its physical expression and loss of biodiversity are poorly documented and poorly understood. Physico-chemical monitoring aspects of this program began in 1977. Intensive monitoring of fauna, flora, water chemistry and groundwater began in 1997. This is a long-term ecological monitoring project.

Aims

Monitor changes in biodiversity, surface water quantity and quality, and groundwater levels at representative south west wetlands in relation to threatening processes (particularly dryland salinity and reduced rainfall), land-use changes and catchment and wetland management, to provide information that will lead to better decision making for wetland management.

Summary of progress and main findings

- Fauna monitoring: all existing data was quality checked. All specimens up to 2011 were identified, a paper on spatial and temporal patterning of invertebrates and waterbirds within the Lake Bryde recovery catchment is in preparation.
- Waterbird communities were surveyed across the Warden Recovery Catchment/Ramsar wetlands and the Gore Ramsar wetlands in November 2013 and February 2014. Waterbird monitoring at Lake Warden is continuing to show that a return to low water levels, partly as a result of engineering works, has resulted in return of waterbird communities observed prior to waterlogging.
- Completed the final report on a study designed to investigate hydroperiod requirements of aquatic invertebrate fauna in Drummond wetlands.
- Surface water monitoring: depth and water quality monitoring was undertaken at 103 wetlands, and data added to the South-west Wetlands Monitoring Program (SWWMP) database and supplied to managers and external researchers. Continuous water level recorders and rain gauges were maintained on nine southern wetlands with high conservation values - especially for Australasian Bitterns - that are under threat. A report on Thirty Year Trends (1981–2010) in water levels and rainfall of all SWWMP wetlands monitored continuously for decadal and multi-decadal periods was drafted.
- Vegetation monitoring for 2013 was completed on a reduced set of wetlands (4) with a focus on recovery catchments and wetlands with high conservation value plant communities.
- Shallow groundwater monitoring and databasing was completed for the 2013 sampling round. Long-term trends can now be determined from the data.
- Report presenting 1977–2012 depth, salinity and pH data for 99 of the 103 currently-monitored SWWMP wetlands was completed, with additional sections concerning recreational use and occurrence of threatened vertebrate fauna.
- A journal article presenting soil electrical conductivity data was published in *Geoderma*.
- Vegetation monitoring data for 2012 was prepared for analysis, and databasing of vegetation monitoring data for 2013 is almost complete.

Management Implications

- Monitoring of depths, salinities and pH of 103 SWWMP wetlands revealed a number of wetlands are undergoing changes that warrant further investigation and corrective management.
- The long-term nature of the project is providing an understanding of the range of variation in biotic communities under different climates and hydrological regimes, and a context in which to assess and predict future changes.
- Surface water management is as important in some Wheatbelt wetlands (e.g. Coomalbidgup Swamp) as groundwater management and a greater focus on surface water is required to maintain wetland health.
- Knowledge of the salinisation effects of rising groundwater and declining rainfall enables prioritisation of conservation efforts in south-west wetlands.

- Hydrological interventions to reduce water levels in waterlogged wetlands, such as implemented in the Warden Recovery Catchment, can be effective at recovering the flora and fauna.

Future directions (next 12 to 18 months)

- Focus fauna monitoring efforts towards the recovery catchments, where results can inform adaptive management, and other wetlands with high conservation value.
- Continue to publish results of the biological monitoring component, including publishing the entire fauna dataset with summaries of 15 year trends.
- Organise a format to enable upload of vegetation monitoring data, including trends to NatureMap.

The effect of wildfire on forest fungi

SPP 1998-015

Team members

R Robinson

Context

Fungi are amongst the most important of forest organisms in terms of their biodiversity and ecosystem functions. Fungi play key roles in decomposition and nutrient cycling, enhance soil structure and nutrient uptake by plants, and provide food for native mammals. Fire impacts significantly on the physical environment in which fungi persist. By monitoring the presence of fungal fruit bodies on burnt sites over time, changes in species composition and abundance can be determined. The results can be included in forest management when making decisions on appropriate fire regimes for the maintenance of biodiversity.

Aims

- Investigate the response of macrofungal communities to fire in karri forest.
- Monitor the succession of fungi on burnt sites in karri forest.
- Collect vouchers and catalogue macrofungi in karri forest.

Summary of progress and main findings

- Validation of species identification was completed and preliminary analysis of data was undertaken.
- Three public presentations were given on the ecology of macrofungi and the response of macrofungal communities to fire.

Management Implications

Results contributed to information on the management of fire for the conservation of biodiversity in eucalypt forest and showed that many species of fungi respond directly to fire or are associated with the post-fire conditions in karri forest. Fungal community structure differs significantly for each year following fire for at least five years. Fire mosaics have the potential to enhance fungal diversity across a landscape.

Future directions (next 12 to 18 months)

- Continue laboratory work to catalogue and identify voucher specimens collected.
- Complete analysis of data from 15-year post-fire assessment.
- Prepare draft paper(s) for publication.
- Prepare Science Information sheet.

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

SPP 1998-007

Team members

M Byrne, D Coates, S Van Leeuwen, S McArthur, B Macdonald, M Millar, E Levy

Context

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

Aims

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

Summary of progress and main findings

- *Eucalyptus leucophloia*—Phylogeographic analysis of 20 populations across the Pilbara Bioregion was carried out with chloroplast microsatellite markers. High haplotype diversity was found in the Hamersley Ranges and Fortescue River regions, indicating these are sites of historical refugia, and low diversity in surrounding areas indicates that they have been recolonised in later climatic periods.
- A paper on genetic patterns in *Acacia ancistrocarpa* and *A. atkinsiana* has been drafted. *Acacia ancistrocarpa* has moderate haplotype diversity with most populations showing specific haplotypes. Nuclear diversity was moderate with little genetic structure across the Pilbara populations of this widespread species. In contrast, the Pilbara endemic, *A. atkinsiana* had low haplotype diversity with little geographic structure. Nuclear diversity was low and genetic differentiation among populations was moderate.
- *Grevillea paradoxa*—Haplotype diversity within populations was low, diversity was moderate overall and there was a phylogeographic signal in chloroplast DNA. Nuclear diversity was low and genetic differentiation among populations was moderate to high with no signal of isolation by distance.
- *Melaleuca nematophylla*—Haplotype diversity within populations was low, diversity was moderate overall and there was a phylogeographic signal in chloroplast DNA. Nuclear diversity was low and genetic differentiation among populations was moderate with a signal of isolation by distance.
- *Mirbelia bursaroides*—Haplotype diversity within populations was low, diversity was moderate overall and there was no phylogeographic signal in chloroplast DNA. Nuclear diversity was moderate and genetic differentiation among populations low to moderate with a signal of isolation by distance.
- *Grevillea globosa*—Haplotype diversity within populations was low and diversity was low overall. There was no phylogeographic signal in chloroplast DNA. Nuclear diversity was moderate and genetic differentiation among populations was low with a signal of isolation by distance.

Management Implications

- Pilbara seed collection zones—The high levels of genetic diversity and low levels of differentiation within *E. leucophloia* and *A. ancistrocarpa* imply that, for these species, seed resources for land rehabilitation and mine-site revegetation programs can be selected from a wide distributional range within the Pilbara. However, phylogeographic analysis of *E. leucophloia* has identified the Hamersley and Chichester ranges as areas of historical refugia, so seed collections for rehabilitation of mine sites using this species should be targeted within the ranges to maintain the diversity of these sites. In contrast, the low diversity and high population differentiation in *A. atkinsiana* indicates that more restricted seed collection zones should be observed.

- *Aluta quadrata*—The significant genetic structure in *A. quadrata* indicates three conservation or management units: Western Ranges, Parraburdoo and Howie's Hole. Given the genetic differences, restricted distribution and size of the populations, a precautionary approach should be taken to seed collections. Establishment of restoration populations within gene flow distance of existing populations should be done with seed from the location of that population. However, mixing seed collections from the three locations for establishment of restoration sites located further away from the existing populations would be a means of maximising genetic diversity for future conservation.
- *Grevillea paradoxa*—Moderate haplotype diversity and low levels of divergence among haplotypes of *G. paradoxa* imply that there are no evolutionarily divergent lineages within this species. Genetic structuring and divergence in the nuclear genome does imply some limitation to pollen dispersal, likely due to territoriality in bird pollinators and an ability to self-pollinate however, and this implies three regional seed collection zones for land rehabilitation and mine-site revegetation programs may be appropriate for this species.
- *Melaleuca nematophylla*—Levels of divergence among haplotypes suggest the population of *M. nematophylla* within the Murchison River gorge be treated as a divergent lineage and not incorporated into seed collection for land rehabilitation and mine-site revegetation programs outside of this area. Low levels of divergence among populations in the nuclear genome implies that seed collections can otherwise be made across wide distributional areas.
- *Mirbelia bursarioides*—Low divergence among haplotypes implies a lack of divergent lineages for *M. bursarioides*. A limited degree of genetic divergence among populations in the nuclear genome suggests that seed collections for rehabilitation and revegetation that encompass the distribution may be appropriate for this species.
- *Grevillea globosa*—Limited haplotype diversity and divergence and limited genetic structure in the nuclear genome imply that seed collections for rehabilitation and revegetation may be made across this species entire distribution.

Future directions (next 12 to 18 months)

- Genetic diversity and phylogeographic patterns will be investigated in four more species in the Pilbara.
- Management implications and seed collection protocols will be determined in the four species from the Midwest region.

Armillaria spread in karri

SPP 1998-006

Team members

R Robinson

Context

Armillaria root disease impacts significantly on the silviculture and management of regrowth karri forests. Levels of infection in young stands increase significantly following thinning on high quality sites. Infection impacts significantly on the mean total volume of a stand in the form of wood defect and mortality in residual crop trees. This study is designed to look at the options for control of *Armillaria* root disease at the stage of first thinning in karri regrowth forests on high quality sites.

Aims

- Investigate control methods of *Armillaria* root disease in karri regrowth forest.
- Investigate the effects of management on *Armillaria* root disease in karri regrowth forest.
- Investigate how *Armillaria* root disease affects karri tree growth.

Summary of progress and main findings

- Re-assessment of *Armillaria* root disease symptoms on trees in the Warren thinning experiment was completed.

- Data was entered and validated, and analysis is being undertaken.

Management Implications

The control of *Armillaria* root disease has been integrated into first-thinning operations in high quality karri regrowth forest

Future directions (next 12 to 18 months)

- Complete analysis of all data collected up to 2012.
- Liaise with the Ecosystem Health Branch to review monitoring and policy regarding *Armillaria* root disease in regrowth karri stands.
- This project will be terminated and ongoing work on *Armillaria* root disease monitoring will be integrated with SPP 2011-020 Long-term stand dynamics of regrowth karri forest in relation to site productivity and climate.

MARINE SCIENCE

ALAN KENDRICK

The broad goal of the Marine Science Program is to ensure Parks and Wildlife's marine biodiversity conservation and management programs are based on good 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. The research and monitoring programs undertaken by the Marine Science Program are based around the research and monitoring strategies identified in protected area management plans and threatened species recovery/management plans, ensuring that all activities are clearly linked to departmental priorities and programs.

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

SPP 2014-005

Team members

G Shedrawi

Context

Penguin Island off the Rockingham coast, south of Perth, is part of the Shoalwater Islands Marine Park and an important northerly breeding location for little penguins, *Eudyptula minor*. The presence of migrating and resident seabirds and the unspoilt beaches makes Penguin Island an important seabird breeding colony and an attractive destination for residents and tourists, who generally access the island by ferry. A small number of visitors choose to wade or swim to the island and Parks and Wildlife managers have identified this activity as a significant risk to visitor safety. Historically, such methods of crossing have resulted in near drownings that require Department staff to rescue people in the water and more recently, a drowning incident. Parks and Wildlife are continuing to implement a range of management strategies to mitigate against this risk, and this project has been established to develop a better understanding of high risk crossings by visitors, thus providing managers with relevant information for the design of mitigation strategies and actions.

Aims

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

Summary of progress and main findings

- Completed installation of a remote camera system for recording little penguin beach arrivals and people crossing the sand bar to Penguin Island.
- Determined the proportion of visitors using the sandbar crossing as opposed to the ferry service for one summer season.
- Identified peak periods and environmental conditions when visitors are using the sandbar to cross to and from Penguin Island, and characterised the different 'user groups' that were making the high risk crossings.
- Refined methods to improve monitoring of visitor sandbar crossings for further summer seasons of recording planned for 2014/2015, and 2015/2016.

Management Implications

Marine park managers now have an improved understanding of penguin breeding and visitor participation at Penguin Island. This new remote monitoring tool facilitates the survey of little penguins, that assists in 'condition' and 'pressure' assessments to provide timely information to managers if there are issues around the condition of penguins or the pressures impacting them. This information is used to design responsive and adaptive on-ground management, and also to support reporting back to the community as little penguins are a threatened species identified as a KPI within the Shoalwater Islands Marine Park Management plan that is audited annually.

From a visitor safety perspective this information allows managers to target visitor risk mitigation strategies to periods of highest risk, and design informed mitigation actions that decrease the chance of high risk crossings and the likelihood of rescues being needed.

Future directions (next 12 to 18 months)

- Collect penguin beach return information to inform managers of penguin nesting activity, and a further two seasons of visitor high risk crossings at Penguin Island (summer 2014/2015 and 2015/2016).
- Develop systems for managing post processing of imagery, and look for options that engender greater community engagement.

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

SPP 2014-004

Team members

RD Evans, S Wilson, M Byrne, R Douglas, B Macdonald

Context

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

Aims

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

Summary of progress and main findings

- Conducted scoping and collecting trip to eastern, central and western regions of the Pilbara.
- Deployed and collected first coral recruitment settlement tiles for temporal study of recruitment processes in Onslow region.
- In-situ assessment of recruit corals on reefs in the Onslow region using quadrats with underwater visual census and digital photos.

- Preliminary planning for coral recruitment study.
- Analysis of Chevron's benthic images to understand size class frequency distribution of corals in the Onslow region.

Management Implications

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

Future directions (next 12 to 18 months)

- Continue collecting tissue samples of organisms and processing of tissue samples for genetic analysis (connectivity study).
- Analyse data on settlement of corals.
- Continue analysing benthic images for coral demographics assessment and reporting.
- Investigate differences between photo quadrats and UVC of coral recruitment in-situ.
- Redeploy coral settlement tiles in February and May 2015 to determine settlement differentials across the period of spawning.

The influence of macroalgal fields on coral reef fish

SPP 2013-006

Team members

S Wilson, T Holmes

Context

Macroalgae are a prominent component of tropical benthic communities along the north-west coast of Australia. Within the Ningaloo lagoon, large fields of macroalgae are a distinct feature of the marine park, covering ~2000 ha. These macroalgal fields are important habitat for fish targeted by recreational fishers and are a focal area for boating activity within the park. Moreover, large seasonal shifts in algal biomass on these and other tropical reefs suggest macroalgae play an important role in nutrient fluxes in Ningaloo and similar systems. Recent work at Ningaloo has quantitatively assessed seasonal variation in biomass and diversity of macroalgal communities and assessed methods for estimating coverage of macroalgae using remote sensing. 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, 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 influence of juvenile fish on replenishment and future adult abundance.

Summary of progress and main findings

- A paper documenting spatial and temporal differences in macroalgal biomass has been published in *Limnology and Oceanography*.
- The results from the study have been presented in an information sheet and on the Ningaloo atlas (<http://ningaloo-atlas.org.au>).
- More general dissemination of the findings has involved public lectures in Coral Bay, an interview on ABC North radio and a report in the Northern Guardian.
- A further manuscript on importance of macroalgal fields for herbivorous and predatory fish has been submitted for publication in *Marine Biology*.

Management Implications

- Improved understanding of the spatial arrangement of macroalgal fields that increase the Department's ability to predict distribution of algal biomass and diversity for spatial planning across marine parks. These surveys of macroalgal communities offer a baseline for future monitoring, evaluation and reporting of condition change in macroalgal communities, especially as they have been identified as susceptible to temperature rises that are associated with climate change.
- Assessment of how abundance and biodiversity of fish recruits relates to the characteristics of macroalgal fields will improve our understanding of which habitat features promote recruitment, a process that supports both ecological (fish communities) and social values articulated in the Ningaloo Marine Park Management Plan and management plans for other tropical marine protected areas. Knowledge of this fish algal relationship improves the Department's ability to predict future abundance of adult fish stock that further contributes to our understanding of species sustainability, particularly those threatened by changes in habitat, climate and fishing pressure.

Future directions (next 12 to 18 months)

Data on the characteristics of algal fields has been collected for two summers and one winter. Further sampling over the next year and a half will provide adequate temporal data to address the objectives stated above.

The Western Australian Marine Monitoring Program (WAMMP)

SPP 2012-008

Team members

K Friedman, K Bancroft, G Shedrawi, T Holmes, M Rule, A Kendrick, S Wilson

Context

A state-wide system of marine protected areas is being established as part of Australia's National Representative System of Marine Protected Areas (MPA). Long-term monitoring of condition of environmental assets and related social values, along with evaluation and reporting, is a recognised state priority, and cross-jurisdictional matters of significance are receiving greater recognition on the road to national environmental accounting. The Department's Western Australian Marine Monitoring Program (WAMMP) is a state-wide, long-term, institutional marine monitoring, evaluation and reporting (MER) program, currently being developed and implemented to increase the efficiency and effectiveness of MPA and threatened marine fauna conservation and management programs.

Aims

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

Summary of progress and main findings

- Measurement of asset condition, related pressure and (management) response information for multiple biophysical assets and passive social values (e.g. finfish, coral, seagrass, mangrove,

penguins, turtles, little penguin, cetaceans, dugongs, water quality, visitor participation and risk) were undertaken across twelve marine parks in Western Australia, extending from Walpole-Nornalup in the south to Lalang-garram Camden Sound in the north.

- Individual status reports that include new and historical time-series information on multiple biophysical assets and passive social values (51 key performance indicators) delivered to marine park managers to enable adaptive management planning and delivery, and to service external audit reporting requirements that are required by the independent statutory body under which marine parks are vested.
- Implementation of a more streamlined information management and audit process, for managing information work-flows and warehousing of the long-term time-series data needed to service marine park needs and the audits conducted by the Marine Park and Reserves Authority.
- Scientific publication in *Ocean and Coastal Management* that describes a model for estimating in-situ water temperature from NOAA sea surface temperature (SST) data at nine sites in four MPA's.
- Train Parks and Wildlife staff, interns and volunteers on monitoring protocols for multiple biophysical assets (e.g. coral, fish, mangrove, Australian sea lions and little penguin communities).

Management Implications

Long time-series datasets have value, as a means of learning from past experience, improving service delivery, planning and allocation of resources, and demonstrating results as part of accountability to key stakeholders. This performance assessment and adaptive management framework allows conservation managers to respond appropriately to changes as they become apparent, and to refine approaches to managing ecological and social assets based on quantitative assessment of change.

Future directions (next 12 to 18 months)

- Implementation of new ecological asset, social and cultural value monitoring for the new Lalang-garram Camden Sound, Eighty-Mile Beach and Ngari Capes marine protected areas.
- Continue to provide marine park managers with the understanding and data they need to allow effective and efficient planning and delivery of adaptive management.
- Continue to provide the information required for external auditing of Western Australia's state-wide system of marine protected areas and threatened fauna programs.
- Continue to increase monitoring, evaluation and reporting focus on social values, anthropogenic pressures and stakeholder participation.

Review, assess and summarise historical data relevant to the management of the proposed Dampier Archipelago Marine Park and Regnard Marine Management Area

SPP 2012-007

Team members

K Friedman, C Nutt

Context

The Pluto LNG Project Offset "d" program includes the requirement to review, assess and summarise historical data relevant to the management of the proposed Dampier Archipelago Marine Park and Regnard Marine Management Area. Large amounts of marine environmental and social data have been collected by a range of agencies and industry in this area since the late 1970s. This project will collate and review this data to assist in providing a comprehensive understanding of the historical condition of biophysical assets and social values of the area.

Aims

- Identify, assess and collate existing biophysical and social datasets relevant to values listed in the indicative management plan for the Dampier Archipelago Marine Park and Cape Preston Marine Management Area.
- Construct an historical time-series of relevance to the conservation of the marine biodiversity and the management of human activity.
- Ensure data is summarised, archived, made accessible and broadly presented to government, industry and the local community.
- Assist the design and implementation of Pluto LNG Project Offset "d" projects (ii), (iii) and (iv).

Summary of progress and main findings

- Over 800 datasets across 14 ecological values have been identified and prioritised for retrieval based on parameters and guidelines set in strategic Western Australian Marine Monitoring Program documents.
- Information management solutions in the form of a data catalogue and data warehouse are being developed and partially implemented to store and make these data sets accessible.
- Key datasets have been accessed from industry (approx. 93 GB received to date of predominantly coral reef communities and water quality related data) and incorporated into the new marine data catalogue and warehouse.

Management Implications

Understanding the effectiveness of current and past management relies on an ability to be able to detect significant change. Access to historical data provides such an opportunity, with improved understanding of historical trends for environmental assets and social values helping to inform time-series baselines for government, industry and the local community. Making historical trends in the condition of marine assets and human use of this region visible to today's managers, recognises and capitalises on past investment in science, helping to speed up the process of identifying existing and potential issues (and risks) where management action may need to be targeted.

Future directions (next 12 to 18 months)

- Complete assessment of historical data relevant to the management of the proposed Dampier Archipelago Marine Park and Regnard Marine Management Area.
- Continue negotiations with data custodians to acquire high-priority datasets identified by the project and ensure final data and meta-data storage solutions meet stated access standards.
- Provide advice and recommendations to assist in the design and implementation of other Pluto LNG Project Offset "d" projects.

North West Shelf Flatback Turtle Conservation Program strategic plan

CF 2011-118

Team members

S Whiting, T Tucker

Context

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

Aims

- Develop a conservation plan for marine turtles in Western Australian as an overarching document to guide marine turtle conservation activities and to provide context for the NWSFTCP.
- Develop a Strategic Plan for the NWSFTCP to outline the scientific, management and communication activities over the next five years in the context of long-term goals.
- Establish the governance arrangements for the NWSFTCP.

Summary of progress and main findings

- Relationships established across the Department with ongoing communication of the aims and operation plan for delivery of the NWSFTCP.
- The formation of the formal NWSFTCP Advisory Committee and Panel of Experts, and development of the Terms and Operational Guidelines for the Advisory Committee.
- Submission of a draft Northwest Shelf Flatback Turtle Conservation Program Plan to the Advisory Committee.

Management Implications

At this early stage of the NWSFTCP, the delivery of a comprehensive plan is setting the foundations of the program that establish a robust program of works within a strategic long-term framework. This offset fund provides an opportunity to fill key gaps in knowledge, establish a long-term robust monitoring program, and deliver management outcomes for flatback turtles whilst more generally providing the framework for conservation and management of all marine turtles in Western Australia.

Future directions (next 12 to 18 months)

- *Strategic Conservation Plan for Marine Turtles in Western Australia* finalised and published.
- *Strategic Plan for the NWSFTCP* finalised and published.
- Submissions to Marine Park managers describing the status of marine turtles and the pressures that impact them, as part of the Western Australian Marine Monitoring Program's reporting function.

WAMSI 2: Kimberley Marine Research Program

CF 2011-117

Team members

K Waples, K Friedman

Context

The Kimberley Marine Research Program (KMRP) will undertake a program of marine research to support the management of the proposed state marine parks at Camden Sound, North Kimberley, Roebuck Bay and Eighty Mile Beach and the coastal waters outside of these proposed marine parks. The KMRP will be developed and implemented through the Western Australian Marine Science Institution (WAMSI), with Parks and Wildlife as lead agency responsible for the direction, coordination and administration of the research program.

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

The research program will be underway between 2012 and 2017 and will involve up to 80 scientists from eight research or management institutions in Western Australia. Aboriginal involvement is a key component to the success of the research program and all projects are engaging with Aboriginal people and developing partnerships with the relevant Traditional Owners to include their participation and to ensure the research outcomes benefit local communities.

Aims

- Ensure the KMRP research projects are developed and delivered in line with the State's priority needs, and to meet Parks and Wildlife and joint manager management strategies for the newly-formed and proposed Marine Protected Areas in the Kimberley.
- Ensure integration of research projects within the KMRP, both in terms of field logistics and science findings, so that the program as a whole produces a clear understanding of Kimberley marine ecosystems and the interactions between them that is useful to management.
- Ensure that the KMRP is undertaken in a culturally appropriate way in partnership with local Aboriginal people and delivered in a way that will help their longer-term aspirations.
- Ensure that knowledge transfer and uptake occurs between scientists, joint managers and decision makers.

Summary of progress and main findings

- Project Agreements in place for 24 of the 25 projects. One project is being re-scoped to ensure it best captures Traditional Owner knowledge, values and needs.
- Engagement with relevant Traditional Owner groups to ensure there is acceptance of KMRP projects and progress in developing partnerships within agreed project delivery plans.
- Field research has been completed for three of the projects and is underway for a further 10 projects.
- All projects have consulted with relevant Traditional Owner groups before commencing research and five projects have included participation by Traditional Owners and/or Indigenous rangers in field work.
- A knowledge uptake strategy has been developed to guide the 'knowledge to action' process and ensure outcomes are fully realised.
- Two meetings to bring all KMRP project leaders together to discuss cross cutting issues and research logistics, in addition to one on one meetings between Project Leader's and the KMRP Node Leadership team to further refine each project's management related questions.
- Numerous presentations to increase awareness of the KMRP, including one to the Royal Society and one to the Broome community. These communications are in addition to local and regional interviews with both Indigenous radio stations and the ABC.

Management Implications

The KMRP outputs will increase our capacity to manage human impacts on the Kimberley marine parks and improve understanding of the ecological and socio-cultural significance of the biodiversity assets of the Kimberley for joint managers, industry and the community. The program also enhances capacity of Aboriginal Rangers and working relationships with Aboriginal communities, thereby increasing the opportunity for more productive joint management in the future.

Future directions (next 12 to 18 months)

- Continue to develop and operate under agreements that define prior, informed consent with Traditional Owners for research on country, and to offer guidance to project leaders and Aboriginal communities on negotiating and documenting annual plans for project partnerships.
- Meetings with stakeholders to ensure the findings and management outcomes of the KMRP meet the expressed needs and interests of Marine Park joint managers, industry and the community.

Spatial variation in the functional morphology of mangroves in the Shark Bay World Heritage Area

SPP 2011-003

Team members

M Rule, A Kendrick, J Huisman

Context

The Shark Bay Marine Park (SBMP) and the adjacent Hamelin Pool Marine Nature Reserve are World Heritage-listed and support a diverse range of iconic marine conservation values. The ecological diversity of SBMP is high because this area is the southern distributional limit of many tropical species and the northern limit of many temperate species.

The mangrove communities of SBMP are the most southern, extensive mangroves on the Western Australian mainland and are recognised as a significant marine park conservation asset, and eastern Shark Bay is listed under the *Directory of Important Wetlands in Australia*. Mangroves in the SBMP display a wide variety of morphologies that are possibly related to the unique oceanographic characteristics of Shark Bay. While mangroves are a key ecological value of the SBMP, the current knowledge of these habitats is inadequate and this deficiency impedes their effective management in the reserve, and the broader World Heritage Area. For example, no significant areas of mangrove habitat currently exist within SBMP sanctuary zones. This project will provide the first comprehensive description of the variation among dense *Avicennia marina* stands in SBMP.

Aims

- Determine variations in the structural morphology of mangrove stands across the SBMP.
- Determine a classification of mangroves within the SBMP based on physical structure and environmental parameters.
- Identify indicators for ongoing monitoring of mangrove community condition.

Summary of progress and main findings

- A paper titled 'Spatial variation in the western white mangrove *Avicennia marina* var. *marina* in Shark Bay Marine Park: does current management zoning adequately protect different morphotypes?' has been submitted to *Conservation Science Western Australia*.
- A paper titled 'Mangrove-associated macroalgae and cyanobacteria in Shark Bay, Western Australia' is in preparation.

Management Implications

This study will identify mangroves of conservation significance in the SBMP and will provide significant information that will assist in future reviews of the SBMP management plan and zoning scheme. The data collected in this study will also assist in developing appropriate long-term monitoring indicators and methods for assessing mangrove community condition.

Future directions (next 12 to 18 months)

This project will be completed with the publication of two scientific papers.

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

SPP 2010-008

Team members

S Field, D Evans, K Friedman, G Shedrawi

Context

The Gorgon Project (GP), which is based on Barrow Island, is one of the world's largest natural gas projects and the largest single-resource natural gas project in Australia's history. The plant will include three 5-million-tonne-per-annum LNG trains, with domestic gas piped to the mainland, and a four-kilometre-long loading jetty for international shipping.

The GP includes a dredging program that involves the removal and dumping of approximately 7.6 M tonnes of marine sediment over a period of approximately 18 months. The Gorgon Dredging Offset Monitoring Evaluation and Reporting Project (Gorgon MER) will investigate the potential impacts of the dredging and dumping activities on selected marine communities within the Montebello/Barrow Islands marine protected areas (MBIMPA). This monitoring will also help inform future environmental impact assessments by improving predictions of the spatial scale and nature of the likely impacts of dredging and dumping activities on sensitive marine communities. Additionally, this project will increase the knowledge base of the MBIMPA.

Aims

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

Summary of progress and main findings

- Planning has been completed for longer term, lower level sampling of coral and fish communities across the MBIMPA's (Phase Two) now that the construction of marine facilities for the Gorgon Project has largely been finalised.
- The first phase Gorgon MER report, which describes potential impacts of marine construction on bio-physical assets has been drafted.

Management Implications

- Phase One of the Gorgon MER project provides Department managers and scientists with a relatively intensive baseline for assessing potential impacts on, and recovery of, coral communities within the MBIMPA, with a particular focus on potential impacts related to the dredging program for the Gorgon Project. Information outputs include temporal condition and related pressure measures for biophysical assets (e.g. coral, finfish and macro-invertebrate communities), that facilitates the Departments management and conservation activity in the MBIMPA.
- The data generated from this monitoring program will also complement Offset 'e' of the Pluto LNG program aimed at improving the capacity of government and industry to manage the impacts of dredging on tropical coral reef communities. The Gorgon MER project also strategically assists the planning for future environmental impact assessments (EIA) by improving predictions of the spatial scale and nature of the likely impacts of dredging and dumping activities on sensitive marine communities.

Future directions (next 12 to 18 months)

- Finalisation and publication of the Gorgon MER Phase One final project report.
- Initiation of fieldwork for Gorgon MER Phase Two (longer-term strategic monitoring) that is closely linked to the activity and reporting of the Western Australian Marine Monitoring Program.
- Completion of peer reviewed publications, and archiving of all data collected.

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

SPP 2009-013

Team members

A Kendrick, M Rule

Context

The Walpole and Nornalup Inlets Marine Park (WNIMP) was created in 2009 to include the entrance channel, both inlet basins and the tidal extent of the Frankland, Deep and Walpole rivers. Invertebrates are recognised as a significant ecological value of the marine park and a key performance indicator (KPI) of management effectiveness. The benthic invertebrate community of the inlets has been described from surveys conducted in 1984 and 1987. The fauna was found to be relatively diverse compared with most estuaries in the south-west of Western Australia because of the predominantly marine conditions that are sustained in the inlets. Few subsequent studies have examined this fauna, and the current knowledge of benthic invertebrates in the system is considered to be inadequate for marine reserve management. Little is known, for example, of how the fauna varies in response to the seasonal hydrological cycle.

Aims

- Determine spatial patterns in the WNIMP benthic invertebrate community.
- Determine temporal variation in the WNIMP benthic invertebrate community, particularly in relation to seasonal changes in the hydrological cycle of the inlet system.
- Assist Parks and Wildlife's Marine Monitoring Unit in the development of methods for long-term monitoring of benthic invertebrate communities in the WNIMP and more broadly across temperate estuarine marine protected areas.

Summary of progress and main findings

- A paper titled 'Spatial and temporal patterns in the distribution of large bivalves in a permanently-open temperate estuary: implications for management' is in press in *Marine and Freshwater Research*.
- An article on benthic invertebrate communities of WNIMP titled 'Cities in the sand' was published in *LANDSCOPE*.
- Approximately 80% of the taxa collected over three years of seasonal fieldwork have now been identified with the assistance of experts. This has included genetic work to identify bivalves of the Genus *Soletellina*, which are the most abundant molluscs in the inlets and are potential indicator species.
- Analysis of spatial and temporal benthic invertebrate community data is continuing.
- A collaborative Parks and Wildlife/Edith Cowan University student camp was held at WNIMP in April 2014, with Coastal and Marine Management course students undertaking a pilot study of bivalve recruitment in the estuary. Data were collected over four days and provided to Parks and Wildlife to assist future research planning.

Management Implications

This study determines how the benthic invertebrate community varies spatially and temporally in the WNIMP. As benthic invertebrates are a KPI for the marine reserve, this knowledge is important in relation to understanding how natural processes and possible anthropogenic impacts influence this community. This study will also assist the implementation of long-term benthic invertebrate community monitoring by the Marine Monitoring Unit and regional staff in the WNIMP.

Future directions (next 12 to 18 months)

- Detailed analyses of the spatial and temporal invertebrate dataset will be undertaken.
- Additional ecological papers will be commenced.

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

SPP 2009-003

Team members

S Wilson, T Holmes

Context

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

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

Aims

- Determine how habitat degradation instigated by climate change and changes in predation instigated by fishing pressures affect the composition of the predator community on Western Australian coral reefs.
- Assess diet of predatory species targeted by fishers.
- Identify microhabitats preferentially used by juvenile fish.
- Assess how variation in fishing pressure and habitat complexity/composition influence predation rates on juveniles.

Summary of progress and main findings

- A paper on diet of predatory fish species was published in the *Journal of Fish Biology* and a second paper on the role of these fish in coral reef trophodynamics is currently being prepared for submission.
- A review article on effects of climate change on coral reef fish was published in *Current Opinion in Environmental Sustainability*.
- A review article on use of coral as habitat by fish was published in *Fish Biology and Fisheries*.
- A book chapter on effects of coral loss on butterflyfish was published.
- Presentations were made at Coral Bay (public presentation) and to Office of the Environmental Protection Authority.

Management Implications

Knowledge of the combined effects of fishing and climate change on fish recruitment will ensure effective management of recreational fishing, which may alleviate pressures placed on coral reef biodiversity. The project will identify appropriate indicators for ongoing monitoring programs and identify finfish species that require protection from recreational or commercial fishing.

Future directions (next 12 to 18 months)

- Examine influence of range shifts of tropical fish into temperate waters.

Spatial and temporal patterns in the structure of intertidal rocky platform communities of the Shoalwater Islands and Marmion marine parks

SPP 2009-002

Team members

A Kendrick, M Rule, J Huisman

Context

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

Aims

- Determine the spatial and temporal patterns in the composition of intertidal reef communities in the MMP, SIMP and the proposed northern extension to the SIMP (comprising Garden Island and Carnac Islands).
- Determine if the intertidal reef communities in management zones protected from extractive activities differ from the intertidal reef communities of otherwise comparable reefs.
- Assist Parks and Wildlife's Marine Monitoring Unit in the development of methods for long-term monitoring of temperate west coast intertidal communities.

Summary of progress and main findings

- A paper titled 'An annotated checklist of intertidal reef invertebrates from Marmion and Shoalwater Islands marine parks' has been submitted to *Conservation Science Western Australia*.
- An article titled 'The last lighthouse' has been submitted to *LANDSCOPE*.
- A paper describing spatial patterns in the intertidal invertebrate communities of the MMP and SIMP is in preparation.
- A paper examining patterns in the diversity of algae on intertidal reefs of the MMP and SIMP is in preparation.
- A draft photographic species identification guide to assist future monitoring of temperate intertidal reefs has been completed and is being reviewed.

Management Implications

This is the first comprehensive spatial and temporal study of the biological communities associated with intertidal reefs of Western Australia's temperate marine parks and reserves. It will provide a baseline understanding of intertidal reef 'condition' in the marine parks in relation to natural processes and possible anthropogenic impacts, and will assist the implementation of long-term intertidal reef monitoring, and management and conservation of their value across Western Australia's temperate marine parks and reserves.

Future directions (next 12 to 18 months)

- Ecological papers from data collected in MMP and SIMP will be published.

- The species identification guide to assist future intertidal reef monitoring in MMP and SIMP will be completed.
- Intertidal reef surveys at Ngari Capes Marine Park will commence next summer.

ECOINFORMATICS

PAUL GIOIA

A major role of the Ecoinformatics Unit is to manage and make available the digital biodiversity assets of the Science and Conservation Division. The unit compiles and maintains corporate databases and data warehouses. In particular, it develops and maintains the online portal NatureMap that publishes maps, lists and datasets of Western Australian species. The unit collaborates on projects involving complex information management and analysis, such as identifying broad-scale patterns of plant biodiversity. It also represents the division, both internally and externally, on various forums that have a significant information management (IM) focus, and provides advice on a range of strategic IM issues. The unit has broad experience in biodiversity knowledge management and strives to effectively communicate the data and information that underlie our scientific knowledge.

Provision of authoritative names of Western Australian taxa

CF 2011-108

Team members

P Gioia, A Chapman

Context

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

Aims

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

Summary of progress and main findings

- Publication information has been substantially revised and edited in anticipation of the hard copy publication of WACensus later this year.
- Flora and fauna statistics can now be produced using a standardised method that is machine readable by other systems such as FloraBase.
- Minor bugs have been fixed and enhancements implemented as required.
- A new version of Max was released providing support for the latest versions of Microsoft Access and resolving a number of bugs.

Management Implications

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

Future directions (next 12 to 18 months)

- Annually publish a hard copy of the Census of Western Australian Plants.
- Smut names are scheduled to be implemented within the 2014/2015 financial year.
- Continue to evaluate the alternative data collection tools, such as those developed as part of the Atlas of Living Australia.

test

Online GIS biodiversity mapping (NatureMap)

CF 2011-106

Team members

P Gioia

Context

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

Aims

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

Summary of progress and main findings

- Development of a new version of NatureMap is now complete, and scheduled for imminent deployment. This version utilises a new mapping engine based on the latest available technology.
- Because of this imminent release, the last 12 months have focused solely on new or updated data content, including Western Australian Museum specimen data (November, 2013), the Atlas of Australian Birds (September, 2013), and threatened fauna (November, 2013).
- There has been an additional focus on historical survey datasets, including Carnarvon Basin (2000) and Buccaneer Archipelago (1982) surveys.
- NatureMap recorded 228 new registrations over the last twelve months, bringing the total from 1520 to 1748, a 15% increase.
- Discussions have continued on the feasibility of using Atlas of Living Australia architecture to implement NatureMap functionality.

Management Implications

NatureMap significantly reduces the time spent searching for point-based biodiversity data as well as easing the process of generating species lists for any area in the state.

Future directions (next 12 to 18 months)

- Continue incorporation of historical survey data into NatureMap.
- The backlog of theme updates can now be implemented using the new NatureMap mapping architecture.
- Implement spatial referencing of journal articles to allow published knowledge to be retrieved in spatial searches.
- Continue discussions on the feasibility of implementing a new version of NatureMap powered by Atlas of Living Australia (ALA) software.

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

SPP 2011-010

Team members

P Gioia, Prof SD Hopper (The University of Western Australia)

Context

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

Aims

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

Summary of progress and main findings

- The bioregionalisation analysis was repeated on the 2012 data snapshot using the same methodology as 2004.
- The analysis was repeated using all grid cells to gain an indication of sensitivity of results to site selection.
- An ordination was performed in addition to the original analysis to provide further insights into the classification.
- Results are currently being evaluated.

Management Implications

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

Future directions (next 12 to 18 months)

- Produce manuscripts for review.

STUDENT PROJECTS

The following reports were provided.

Genetic diversity and phylogeography of Australian cats

Scientist

D Algar

Student

K Koch

Progress report

Biodiversity is not only threatened by habitat loss, climate change and pollution, but also through the threat from invasive species. The impact of introduced species is immense and causes substantial ecological and economical costs worldwide. With the start of domestications of the African wildcat (*Felis lybica*) in the Near East, the transport of house cats (*Felis catus*) around the world as commensals and domesticates commenced. The general aim of the thesis was to investigate the impact of invasive feral cats as well as underlying population genetic structures, diversity and phylogeography in the context of the demographic history in Australia and Hawaii. Studies confirmed that the main introductions of cats to Australia began in the 19th century via ships of European settlers, traders and workers. Similarly, the research confirmed cat introductions to Hawai'i by European traders and explorers, which has had devastating effects on Hawaiian endemic species.

Population genetic approaches are able to give insights into population genetic structure diversity and kinship, thereby enabling individually adapted control efforts to be more cost effective and successful. A lack of isolation by distance between populations of Hawai'i and Australia indicated that trade routes, such as the 'Golden Round' of the maritime fur trade, enabled an association between far off global cat populations. Multiple introductions to Australia and intermixing with domestic breed cats resulted in feral cat populations that show no signs of reduced genetic variability. This study also revealed the advantages of bioproxies in combination with phylogeography enabling inference and reconstruction of introduction routes, history and origin of invasive species. Genetic signals of historically introduced genotypes are still discernible on islands with low number of introductions over time and thereby low intermixing with domestic fancy breeds. Feral cats' adaptability as an invader was reconfirmed and possible underlying genetic mechanisms enabling their success as a global invader ('global supercat') were discussed. Research into the feralisation process of cats will provide new information regarding the domestication of cats, the genetic basis of feralisation and allow additional insights into cats' adaptation potential.

This research was completed in 2014 and a PhD awarded. One manuscript has been accepted for publication: - Koch, K., Algar, D. and Shwenk, K. (accepted). Population structure and management of invasive cats on an Australian island. *Journal of Wildlife Management*. Two other manuscripts have been submitted.

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

Scientist

D Algar

Student

N Dybing

Progress report

Overall, a total of 66 cats (30 male and 36 female) and 101 rats (47 males, 53 females and one not recorded) collected from Christmas Island have been necropsied and samples collected for further

testing. A high prevalence of parasitic infection was found in these hosts with greater than 84% of both cats and rats found to be harbouring at least one parasite species and up to six (for cats) and seven (for rats) different parasite species (total infracommunity richness, ICR). Overall, 18 different helminth genera were represented, with a local richness of 10 species identified in cats (representing four Phyla; Nematoda, Cestoda, Trematoda, and Acanthocephala) and 12 species identified in rats (three Phyla; Nematoda, Cestoda, and Acanthocephala). The local richness and total infracommunity richness found in this study is higher than expected. This is due to the island syndrome which dictates that island communities should typically have a high prevalence but a low richness of parasite species due to the founder effect. However this study has found an unusually high local and infracommunity richness, the reasons of which are still to be elucidated.

This study detected no significant correlations with body condition and parasite community ecology in cats; however overall presence of parasites and total infracommunity richness is found to be significantly correlated with body condition in rats. Gender was also found to play a role in parasite community ecology with female cats being more likely to harbour a greater total and visceral infracommunity richness as well as intensity of the bile duct fluke, *Platynosomum concinnum*. In opposition to this male rats were more likely to have a high intensity of the tapeworm, *Taenia taeniaeformis*. In addition to a high number of parasites that have a potential conservation and zoonotic significance, this study also expands the geographic range of eight parasite species as well as the discovery of a potentially novel Spirurid species in rats. These results indicate that a suite of parasites were inadvertently introduced to Christmas Island along with the introduction of both cats and rats. A number of these parasites require suitable intermediate hosts to persist and given the paucity of mammalian species on Christmas Island, we need to consider the involvement of alternative host species in maintaining transmission cycles. Molecular screening of tissue samples for *Leptospira* spp. in both cats and rats is due to be performed shortly. Screening is also underway for the presence of feline and rodent *Hepatozoon* spp. and piroplasms e.g. *Babesia* spp. with preliminary screening producing positive results.

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

Scientist

N Burrows

Student

M Wysong

Progress report

Research investigating the interactions between feral cats and dingoes at Lorna Glen began in the winter field season of 2013. During this time we initiated a pilot camera trap study to trial different camera trap techniques and investigate changes in predator activity following annual Eradicat baiting. Eighty cameras were placed either alongside roads or 100m off roads and were either left unbaited or else baited using an audio call lure. The study showed that the best method for detecting both feral cats and dingoes was to deploy either baited or unbaited cameras along roadsides. Cameras alongside roads that were baited showed a slightly higher detection rate although this difference was not significant while cameras off road showed virtually no detections whether baited or unbaited.

Using the on-road camera data from this study we also examined activity levels of feral cats and dingoes before, during, and after Eradicat baiting. The results of this study showed that activity of both predators (measured by the number of photo captures per trap night) decreased immediately following the baiting. However, by 30 days post-baiting, dingo activity had decreased to about 23% of pre-bait levels whereas cat activity increased to near pre-bait levels. By 60 days, dingo activity rebounded to about 53% and cat activity fell to 45% of pre-bait levels. This suggests that high levels of dingo activity may have some role in suppressing cat activity.

The current phase of research for the project seeks to investigate fine-scale habitat use and diets of these two species to better understand their extent of spatial and dietary overlap. At present, we have deployed 136 camera traps across three major habitat types. This study will run for 21 days prior to the annual Eradicat baiting and again for 21 days starting two weeks after the baiting. An occupancy

modelling approach will be used to analyse this data and will help us understand habitat use of dingoes and feral cats and how this habitat use is impacted by baiting.

To complement the current camera trap study, we have also fitted 16 dingoes and 21 feral cats with high precision GPS collars. These collars take a location fix every two or four hours and will give us detailed information on the movements of these predators through space and time and also help us understand how the baiting impacts their movement ecology. Finally, by analysing scat contents of these species we can get a good understanding of both their level of dietary competition and the impacts that these predators have on their prey species. To date, we have over 100 scats collected of each species and collections will continue until the end of 2014.

Investigation of taxonomic boundaries in the *Tetratheca hirsuta* Lindl. complex

Scientist

R Butcher, K Thiele, M Byrne

Student

E Joyce

Progress report

The *Tetratheca hirsuta* auth. complex is the last remaining unresolved complex in the endemic Australian genus *Tetratheca*. The complex comprises the highly variable *T. hirsuta*, as well as two phrase-named, conservation priority taxa *T. sp.* Boonanarring and *T. sp.* Granite. The primary aim of this study was to determine whether *T. sp.* Boonanarring and *T. sp.* Granite warrant formalisation as taxa distinct from *T. hirsuta*, and if so, at what rank. As part of the resolution of the species complex, the study also aimed to test Thompson's (1976) assertion that individuals with large leaves and straight white stem hairs are *T. hirsuta* rather than the sister species of the complex, *T. hispidissima*. An integrative approach incorporating morphometric multivariate analysis, Elliptic Fourier Analysis of leaf shapes, and phylogenetic analysis of chloroplast (*ndhF-trnL*, *rpl16*, *trnS-trnG5'2S*) and the nuclear ribosomal DNA region ETS was used to resolve taxonomic boundaries within the *T. hirsuta* species complex. Morphological data show strong morphological divergence between *T. sp.* Boonanarring, and *T. hirsuta*, and suggested that the morphological concept of *T. sp.* Granite should be expanded to include some morphotypes of *T. hirsuta*. In addition, morphological analysis indicated that individuals with large leaves and straight white stem hairs are more similar to *T. hispidissima* than to *T. hirsuta*. Phylogenetic analysis of the ETS region showed congruence with morphology, indicating that these morphological groups are also genetically divergent. In contrast, phylogenetic analysis of chloroplast regions yielded low resolution, perhaps due to incomplete lineage sorting and/or introgression. These results suggest that the groups of *T. hirsuta*, *T. sp.* Boonanarring and an expanded concept of *T. sp.* Granite have morphologically and genetically diverged recently, and that they warrant formal recognition as distinct taxa at subspecies rank. Taxonomic resolution of the *T. hirsuta* complex will help inform the conservation prioritization and subsequent management of these taxa and aid future research efforts on this complex and the wider flora of the South-west Australian Floristic Region.

The genetics, essential oil composition and factors controlling the biosynthesis of sesquiterpenes in Western Australian sandalwood

Scientist

M Byrne

Student

J Moniodis

Progress report

Sandalwood oil is one of the world's most valuable essential oils. Western Australian sandalwood, *Santalum spicatum*, is one of seven commercially valuable sandalwood species well known for its pleasant fragrance and importance to many Asian cultures. *S. spicatum* is currently harvested from natural stands and, due to past exploitation combined with slow regeneration and habitat loss, there is

concern over the sustainable management of this species. Plantation production alleviates pressure from natural populations and ensures a sustainable supply of sandalwood in the future. Mature heartwood of *S. spicatum* contains a diverse array of cyclic and acyclic terpenoid skeletons, including bergamotene, farnesene, santalenes and the highly sought after fragrance ingredients, the santalols. Oil production is not consistent with either heartwood yield or composition, so the current research attempts to better understand this variation by investigating the natural genetic and chemical diversity, genes involved in oil biosynthesis, and the different environments in which *S. spicatum* grows in Western Australia.

Several P450 candidates have been selected from genomic libraries derived from *S. album* and *S. spicatum* wood tissue and tested in a yeast system that has successfully produced the santalol precursors in vivo. A 454 library for *S. spicatum* has been constructed to enable further characterisation of genes in order to advance plantation development through improved selection and to reduce strains on natural populations. This gene-mining approach has enabled the characterisation of a fourth terpene synthase (TPS) from *S. spicatum* and identification of four new TPS genes. A chemotaxonomic investigation of approximately 200 individuals distributed throughout the Wheatbelt (predominantly), Goldfields, Shark Bay and Carnarvon has been completed to identify specific chemotypes. Results suggest chemical diversity within and between regions, with some individuals exhibiting high santalol and low farnesol content, an undesirable constituent. An α -bisabolol chemotype may be present in the Goldfields as well as an α -santalol chemotype in northern trees. For these individuals, genetic analyses using microsatellite data are being applied to aid understanding of the genetic structure of this species and the relationship to heartwood oil content. Results confirm previous studies on the presence of two genetic groups of *S. spicatum* in the arid north and semi-arid south-west. Environmental data, including host species and distances, tree height, diameter, soil type and pH and rainfall have been collected from the field to carry out statistical analysis to identify any significant relationships between oil yield and composition, genetics and these various environmental factors. Statistical results thus far have identified santalol and farnesol as two key components driving the variability in heartwood chemistry, which is important for future breeders who wish to select trees with high santalol content and conversely low farnesol content. A relationship between genetic distance and oil composition was also found, indicating a geographic component to oil composition. Results of the studies will be applied to the future conservation of *S. spicatum*, improvement of plantation management with the potential of metabolic engineering of desirable oil constituents in vitro.

Ancient, terrestrial islands in a semi-arid landscape: patterns of genetic diversity in regional endemics of the Yilgarn Banded Iron Formations

Scientist

M Byrne, D Coates

Student

H Nistelberger

Progress report

Species with restricted distributions, known as short-range endemics (SREs) are more susceptible to extinction than those that occupy a wide range and variety of habitats. The Yilgarn Banded Iron Formations (BIF; 500km north-east of Perth) are biodiversity hotspots that harbour many SREs. This project will examine the genetic diversity and structure present in three, co-occurring Yilgarn SREs in order to determine their evolutionary history and to identify regions of high genetic diversity and therefore conservation significance.

Genetic data, using selected chloroplast DNA markers, indicated low genetic diversity and some genetic structuring in both plant species. Nuclear data in *B. arborea* is also indicating low levels of genetic variation and structure. Results for the millipede *A. bamfordi* using selected mitochondrial DNA markers indicated genetic structuring across BIF ranges, with a pattern indicative of an historical vicariance event leading to isolation of BIF populations during the mid-Pleistocene around one million years before present. Both mitochondrial and nuclear genetic markers show higher genetic diversity in the large, more topographically complex BIFs and this has significant conservation implications for the future management of the species. This project has now been completed and a PhD thesis submitted.

Factors that affect seedling establishment and the implications for the translocation of species at risk of extinction

Scientist

D Coates

Student

C Allen

Progress report

To assess natural recruitment success amongst species and better inform translocation success criteria, seedling growth and mortality was monitored at three burnt sites, over two seasons, for a range of *Acacia* and *Banksia* species. Further investigation of translocation success criteria was carried out through experimental translocations of Critically Endangered *Banksia ionthocarpa* ssp. *ionthocarpa* and *Acacia awestoniana*. In *Banksia ionthocarpa* ssp. *ionthocarpa* survival of seedlings after two years was high at 75%, with seedlings in plots that were automatically watered weekly during summer showing increased survival and enhanced growth when compared with seedlings that were manually watered once a month. Of three different microhabitats seedlings had higher survival and grew most in the low heath plots. In *Acacia awestoniana* survival of seedlings after two years was very high at 81%, with treatments not showing significant differences with respect to survival, although there were substantial differences in terms of growth. Plants that were watered weekly or monthly during summer showed enhanced growth when compared to non-watered plants. A PhD thesis has been submitted.

How best can managers measure on-going change in coral condition and related pressure metrics at sites where there is high levels of human use?

Scientist

K Friedman

Student

A Swarts

Progress report

Observed declines in coral cover are the result of environmental stressors, including increased sea surface temperatures, sedimentation, eutrophication, storms and crown-of-thorns starfish outbreaks. These impacts are compounded at a site level through non-extractive recreational activities such as snorkelling, scuba diving and reef walking. Ningaloo Reef provides substantial opportunities for snorkelling and various recreational activities, which comes with the potential for direct physical damage to corals through trampling, fin contact, standing on corals and re-suspension of sediment. This study describes the spatial patterns and behaviour of snorkelers within a high-use site, Oyster Stacks, in Ningaloo Marine Park, using novel integration of GPS and GIS technologies. Fish observations and benthic analysis were also performed to determine substrate impacts from snorkelling activity by comparing high and low trafficked areas. The study concluded that snorkelling activity was not causing substantial ecological disturbance to the shallow water reef at Oyster Stacks. However, a community shift from a more fragile and dense habitat to a more sparse and robust community was noted. Proactive and adaptive management is recommended for Ningaloo Marine Park to help reduce the potential impacts on coral communities from snorkelling activity.

Trypanosomes of some Western Australian mammals: phylogenetics

Scientist

A Friend

Student

J Austen

Progress report

Morphological and phylogenetic characterisation of trypanosomes isolated from both the Gilbert's potoroo (*Potorous gilbertii*) and quokka (*Setonix brachyurus*) from Two Peoples Bay, Albany, and Bald Island, has been completed. Characterisation has identified a novel species of trypanosome *T. copemani* affecting Western Australian native marsupials. Phylogenetic analysis has shown that *T. copemani* is closely related to the South American trypanosome *T. cruzi*, the etiological agent of Chagas disease known to be infective to both a wide variety of animal species and humans. The tick species *Ixodes australiensis* has recently been identified as the vector of *T. copemani*. Motile trypanosomes were found in sections of tick midguts and haemolymph, 49 and 117 days after tick collection, with sequencing showing 100% homology to *T. copemani* (genotype A). Detection of trypanosomes within tick faeces suggests that the transmission of *T. copemani* from vector to host is via the faecal-oral route. The survey to establish the prevalence of blood parasites (trypanosomes and Theileria) and gastrointestinal parasites (Eimeria, Giardia and Cryptosporidium) isolated from quokkas from three geographical locations (Two Peoples Bay, Bald Island and Rottnest Island) is still in progress. To date no trypanosomes have been detected in quokkas captured from Rottnest Island. These results show that a naive population of quokkas does exist and given the potential pathogenicity of trypanosomes when encountering a new host species, wildlife management is therefore crucial, particularly when dealing with species of conservation importance.

Fire regime responses of biological soil crusts in eucalypt woodlands of south-west Australia

Scientist

C Gosper

Student

B Lake

Progress report

This project assessed changes in biological soil crust cover and function (changes in nutrient dynamics) of gimlet (*Eucalyptus salubris*) woodlands over a multi-century time-since-fire chronosequence. Biological soil crusts are complex communities of soil inhabited by bacteria, cyanobacteria, algae, fungi, lichen and bryophytes, and are important components of arid ecosystems worldwide. Disturbances such as wildfire may impact on crust composition, cover and function, but it is poorly known what these changes are and over what time scales crust communities recover after fire.

Changes in the composition and cover of biological soil crust communities occurred with time since fire. Lichen richness increased with time since fire, while bryophyte richness remained largely stable. Overall biological soil crust cover declined with time since fire, with a range of mosses contributing high cover in the immediate post-fire period. Like other biota, biological soil crust communities show distinct successional changes with time since fire in gimlet woodlands.

Systematics of *Sargassum* (Phaeophyceae) in Australia

Scientist

J Huisman

Student

R Dixon

Progress report

This project comprised taxonomic and biogeographical studies on Australian members of the brown algal genus *Sargassum* and its close relatives, employing morphological and molecular techniques to investigate generic, subgeneric and species level boundaries, assisted by analyses of sequences from the nuclear, mitochondrial and chloroplast genomes; ITS-2, *cox3* and *rbcL-S*. The resulting phylogeny indicated the genus *Sargassum* as presently constituted to be polyphyletic, with closely related genera nested within. Combined with morphological observations, these results instigated several taxonomic transfers proposed at the species, subgeneric and generic level.

Initial components of this project investigated the two lesser-known *Sargassum* subgenera; *Phyllotricha* and *Arthrophyucus* (Dixon *et al.* 2012, 2014), concluding that *Sargassum* was polyphyletic if subgenus *Phyllotricha* was included. To remedy this, the subgenus was restored to genus level as *Phyllotricha* Areschoug and several *Sargassum* species were transferred to it. The genetic variation within species of the former *S.* subgenus *Phyllotricha* was sufficient to recognize species-level variation and, for the most part, concurred with the current morphology-based taxonomy; thus most existing species were retained (albeit transferred to another genus), and just one reduced to synonymy.

The investigation into *Sargassum* subgenera *Arthrophyucus* and *Bactrophyucus* found the two taxa were not genetically or morphologically distinct, and their past and contemporary recognition was essentially based solely on their geographical distribution. Molecular analyses demonstrated that species of *S.* subgenus *Arthrophyucus* were genetically nested within *S.* subgenus *Bactrophyucus* section *Halochloa*, and this study proposed to transfer them accordingly, subsuming the name *Arthrophyucus*. This newly circumscribed *S.* subgenus *Bactrophyucus* has an antitropical and disjunct distribution, being present in the temperate to subtropical northwestern Pacific Ocean and the temperate to subtropical southern Indo-Pacific, but not at all in tropical equatorial waters.

The third aspect of this project focused on the north-western Australian Fucales and was based on extensive new collections made throughout tropical Western Australia. The order Fucales in this region is composed of five genera: *Hormophysa*, *Sargassopsis*, *Sargassum*, *Sirophysalis* and *Turbinaria*. Of these, *Sargassum* comprised 10 of the 16 species, and all but one of these was in subgenus *Sargassum*. A number of species new to the area were added as range extensions, including *Sargassum marginatum* (known previously from India, Sri Lanka and Indonesia), *Sargassum paradoxum* (known previously from temperate Australia), *Sargassum aquifolium* (common and including several previously recognised species as synonyms), and the new species *Sargassum rasta* (Dixon & Huisman, in press).

Molecular taxonomy, phylogeography and population genetics of the *Grevillea thelemanniana* complex

Scientist

G Keighery

Student

T Hevroy

Progress report

A phylogenetic and phenetic assessment of genetic variation within and among species in the *Grevillea thelemanniana* subclade indicated that conservation listed taxa *G. delta*, *G. humifusa* and *G. thelemanniana* ssp. Cooljarloo, along with an unlisted taxon *G. pinaster*, are distinct species. The strong support for *G. thelemanniana* ssp. Cooljarloo to be recognised as unique species has conservation implications given its location close to current mining operations. More detailed landscape genetic studies on *G. thelemanniana* ssp. Cooljarloo revealed barriers and corridors for gene flow within and among its riparian populations and will be considered in relation to the future management of these populations. This work has now been completed and a PhD thesis has been submitted.

Feeding ecology of Pomacentridae and its ecological role in fish herbivory in temperate algal-dominated reefs

Scientist

A Kendrick

Student

F Vitelli

Progress report

The aim of this study was to determine the trophic role of pomacentrid fishes as herbivores on temperate algal-dominated reefs, with a particular focus on the abundant species *Parma mccullochi*. The study was undertaken in Marmion Marine Park and determined the diet of this species, including ontogenetic changes, and the impact of grazing by pomacentrids on algal production and the composition of temperate reef algal communities.

Parma mccullochi was found to be a strict herbivore, feeding almost entirely on foliose and filamentous red algae and the diets of juvenile and adult fish did not differ. Electivity indices indicated that *P. mccullochi* specifically selected these algae. Macroalgae differed significantly inside and outside *P. mccullochi* territories and a caging experiment in territories indicated a moderate effect on the composition of recruiting algae.

This thesis successfully passed examination and a paper titled 'The territorial herbivorous fish *Parma mccullochi* (Pomacentridae) strongly influences algal assemblages in temperate reefs' is currently in review at *Marine Ecology Progress Series*.

The role of *Kyphosus* spp. in reef ecosystems

Scientist

A Kendrick

Student

A Turco

Progress report

Little is known about herbivory by fishes in temperate reefs and even less about the species that play an important role in this process. Kyphosids are an abundant family of herbivorous fishes widely distributed in the southern hemisphere, and especially in both temperate and tropical waters of Australia; however, the ecology of these fishes in temperate latitudes is poorly understood. The aim of this project is to determine the role of kyphosids in algal herbivory in reef ecosystems, and the factors affecting their grazing activity.

Field studies in Marmion and Ningaloo marine parks have now been completed, as have pilot studies on how to best survey kyphosids and assess their diets. A quantitative study of habitat use has been completed and all fishes required for laboratory work in the study have been collected. These fishes are currently being processed to compile data sets on morphology and diet.

Fire weather

Scientist

L McCaw

Student

M Peace

Progress report

Weather is a primary driver of bushfire behaviour. Much of the science linking interactions between fire weather and fire behaviour was established in the 1960s and 1970s, but new advances in understanding and computer modelling capability provide the scope to better understand the interactions of weather and fire behaviour. Coupled fire-atmosphere models have the ability to capture feedback loops between the fire and the atmosphere, enabling better understanding of how a fire may modify the environment in which it is burning. This is of particular importance during large-scale, high-intensity bushfires. This project aims to explore the capabilities and applications of the Weather Research and Forecasting (WRF) model by examining case studies of actual bushfires, and by running idealised simulations where the sensitivity response to different input variables can be tested. Case studies include forest and shrubland fires in southern Australia. A detailed technical report examining

significant aspects of the behaviour of the Kangaroo Island bushfires of December 2007 has been published. A case study of unexpectedly severe fire behaviour during a prescribed burn in October 2010 at Layman block east of Margaret River was published in the *Australian Meteorological and Oceanographic Journal*.

The WRF model has been used to investigate the effect of coupling between the fire and the atmosphere. This has been done by simulating the growth of well-documented fires with and without the coupling function in the WRF model being enabled. Clear differences in fire behaviour have been observed between these contrasting model runs, and differences are consistent with known fire behaviour phenomena. A paper describing simulations of the 2007 D'Estrees fire is in review with the *Journal of Applied Meteorology and Climatology*, and two manuscripts are in review with the *International Journal of Wildland Fire*. A PhD thesis was submitted to the University of Adelaide in May 2014.

Ecology and taxonomic differentiation in the Australian water rat and implications for its conservation status in Western Australia

Scientist

K Morris

Student

K Bettink

Progress report

The ecology and genetic structure in the Australian water rat is being investigated to provide information to support management. In total 94 samples were obtained from across PNG, Northern Territory, eastern Australia, the Kimberley, Shark Bay, south-west Western Australia and Barrow Island. This set broadly represented almost all of the species' distribution. Analysis of nuclear DNA using microsatellite markers has been completed and draft chapter is currently in review. Markers revealed significant regional genetic structure across species range, with particularly high levels of differentiation recorded in south-west Western Australia, Barrow Island and Tasmania compared to remainder of regions. This genetic divergence appears to match phenotypes (defined by pelt colouration) observed in Barrow island and south-west Western Australian populations.

Where sample sizes were sufficient for within-region analysis, substantial genetic structure was found within south-west Western Australia and the lower Murray River / Adelaide region in South Australia. Significant structure was found within south-west Western Australia at fine spatial scales (<30km), broadly correlated with hydrological catchments, and tributaries and dominant vegetation, with relationships to habitat connectivity. Results from Barrow Island indicate a highly inbred, insular population in low abundance.

These findings have important implications for management and conservation of the species, particularly in Western Australia. The new information will contribute to resolve the species' taxonomic status - review of the taxonomic and conservation status particularly of south-west Western Australia and Barrow Island populations is required. The level of differentiation among populations needs to be taken into account in any translocation program.

Genetic consequences of mammal translocations in Western Australia using case studies of dibblers, boodies and black-flanked rock wallabies

Scientist

K Morris

Student

R Thavornkanlapachai

Progress report

This project investigates genetic factors that will contribute to improved fauna translocation success.

Investigation of the fine-scale genetic structure of a mainland dibbler (*Parantechinus apicalis*) population in and around Fitzgerald River National Park (FRNP) using spatial autocorrelation suggests a significant relationship between genetic and geographic distances between trapping locations. Dibblers located at least 20km away were less likely to be related than dibblers found within 20km.

Genetic and demographic data are being assessed in dibblers from the translocated Escape population, Boullanger population and Whitlock population. Genetic data has been collected, and demographic data of the Boullanger and Whitlock populations are being gathered from the past records.

The animals for the dibbler translocation to Escape Island were sourced from populations on Boullanger and Whitlock islands that are genetically distinct and have slightly different body sizes. Genetic analysis show evidence of genetic mixing which started from the captive bred colony and continued in the Escape population. However, the mixing seemed to bias toward the Boullanger ancestor, and appears to be size related. Females were observed to preferred heavier males. A low effective population size of approximately eight dibblers was estimated from the genotypic data. Morphological comparisons between different offspring groups, after taking gender differences into account, showed no significant differences except for the head length. However, the sample size was small. Population viability analysis suggested the Escape population will persist for another 70 years. A supplementation as low as seven pairs of dibblers every 10 years can prolong population's persistence.

Investigation of a burrowing bettong translocation to where animals were derived from two genetically and morphologically distinct source populations, Barrow Island and Dorre Island, showed evidence of genetic mixing. The new population had higher genetic diversity in both nuclear and mitochondrial DNA than its parental populations. However, the results suggested a genetic bias toward larger Dryandra bettongs. Based on mtDNA, 70% of interbred offspring were born from Dryandra mothers and Barrow Island fathers. This suggested that the uneven founder proportion from each source population may influence the genetic bias. Offspring morphology showed a positive relationship between the offspring body size and the parental genetic percentage, where the interbred offspring were larger than expected.

Factors affecting fauna translocation success

Scientist

K Morris

Student

J Dunlop

Progress report

Vertebrate fauna translocations, particularly to mainland sites, have a low rate of success (<30%). One potentially contributing factor that has been poorly studied is the impact of parasite loads and pathogenic disease in founder individuals during the stressful establishment period. Each individual carries many species of ectoparasite, enteric parasites and haemoparasites, which may impact directly or indirectly on the host or other species in the environment of the establishing population. For example, blood parasites in the *Trypanosoma* group have been closely associated with the decline of the woylie, *Bettongia penicillata*. This work aims to assess the survivorship impacts of disease and parasite load within the establishing population of golden bandicoots (*Isodon auratus*) and boodies (*Bettongia lesueur*) during the first 18 months of translocation.

We experimentally manipulated the population by regularly dosing half the animals with a broad spectrum antiparasitic treatment in order to disrupt the life cycles of a variety of ecto, enteric and haemoparasites. During this intensive monitoring, other demographic and life history data were collected, as well as biological samples such as blood, DNA and faecal samples. Progress to date includes longitudinal trapping and data collection following the release of 160 golden bandicoots from Barrow Island and 170 boodies from Dryandra and Barrow Island. Approximately 800 blood samples were analysed for species-specific detection of *Trypanosoma copemani* and *T. vegrandis*. Ectoparasites were identified to species level to determine whether there has been a change in species

diversity in the new environment, and to determine the effectiveness of the antiparasitic treatment. Presence of these trypanosomes and ectoparasites were added to models of survivorship to determine if there was a relationship, as well as to follow the pattern of infection across the population. Skeletal and mass measurements, body condition and fecundity of golden bandicoots released at Lorna Glen and Hermite Island were compared to long-term monitoring data from the source population. Upon establishment at both new sites, translocated males increased in condition (i.e. body mass but not skeletal size) and females showed an increased reproductive output. Bandicoots born at translocation sites were significantly larger and heavier ($P < 0.0001$ and $P < 0.0001$ respectively) than the founders from the island population within 18 months of establishment. This change in skeletal size, mass and fecundity took place in a single generation at both mainland and island translocation sites, suggesting that the response is not one of evolution by natural selection. This study demonstrated that the small size of golden bandicoots on Barrow Island is not a genotypic response to selective pressures, but rather a phenotypic response to conditions on the island. When translocated to vacant ecological niches, they have the capacity to produce offspring with increased body mass, size and reproductive output. We suggest that ecological processes relating to resource limitation drive 'island dwarfism' in *I. auratus*.

This PhD study has been completed and the thesis is being prepared.

Breeding systems and phylogeography of selected saline lake invertebrates

Scientist

A Pinder

Student

D Quek

Progress report

Western Australian salt lake systems have very high rates of endemism within their flora and aquatic invertebrate fauna. This has largely been revealed through morphological taxonomic studies across fairly limited geographic extents. *Parartemia* brine shrimp are an important component of Western Australian salt lake systems and this endemic genus represents a greater concentration of brine shrimp diversity in Western Australia than anywhere else in the world. Many *Parartemia* species appear to be restricted in distribution while others are apparently widespread (at least based on morphological identifications), occurring across multiple isolated salt lake systems. This project aims to investigate whether these widespread species represent single genetic lineages (indicating regular dispersal, e.g. by waterbirds, wind-blown eggs or flooding) or a series of spatially restricted ones. The project will also investigate levels of genetic diversity within salt lakes and the levels of connectivity between populations at various scales. This knowledge will contribute to planning for the conservation of salt lake biodiversity by elucidating the spatial scales which are relevant to the conservation of salt lake systems.

Samples of three species of *Parartemia* from the Esperance region have been collected. Over 100 potential microsatellite loci from *P. informis* were identified and tested for suitability for population genetic studies of selected species. Amplification of COI and 16S regions of the mtDNA from selected species of *Parartemia* was tested.

Assessment of mitochondrial and especially microsatellite markers, proved to be difficult for *Parartemia*. All attempts to amplify microsatellite loci from any of the *Parartemia* species collected were unsuccessful. One set of 16S primer designed in the study was able to amplify a small number of *P. longicaudata* from two locations about 340km apart.

Preliminary genetic results and analysis showed that although the specimens were morphologically similar, they had very divergent 16S haplotypes (7.8 - 9% sequence divergence) and formed separate groups in a haplotype network and phylogenetic tree. However, the amount of divergence between specimens from the same site was very small (0.6 - 1.1%). This might indicate that the morphospecies *P. longicaudata*, might actually comprise two or more cryptic species.

Nutrient movement and its impact on aquatic invertebrates as a food source of waterbirds between different wetland suites within the Lake Warden Wetland System

Scientist

A Pinder

Student

J Lizamore

Progress report

The Lake Warden wetland system is one of the six Natural Diversity Recovery Catchments established to protect and/or recover biodiversity under threat from salinisation in the agricultural south-west. This wetland complex is also listed under the Ramsar Convention to protect wetlands of international importance. Waterbirds, including significant populations of resident and migratory shorebirds, are a key biological asset of this system and are the main drivers behind decisions to list the wetlands under the above mechanisms. Lake Warden once supported the largest populations of shorebirds within the system, but altered hydrology due to catchment clearing led to the virtual elimination of shorebird habitat. Engineering works have been installed to reduce inflows to Lake Warden and this has resulted in increased shorebird habitat, with positive signs of shorebird population recovery. However, the long-term management of this lake is dependent on a much more sophisticated understanding of its hydrogeochemistry and ecology. This has been demonstrated recently by the fact that salt loading over the last 20 years (unaccounted for in previous models) means that the lake may now be too salty (at the reduced depths) to maintain sufficient food resources for large shorebird populations. This project aims to produce hydrogeochemical and biological models for Lake Warden, linking hydrology, water chemistry (including salt and nutrient budgets) and elements of the biota (invertebrates and waterbirds). Such models will allow more refined management of the system and its catchment for recovery of its key biological assets.

Surface and groundwater monitoring is continuing. Waterbird monitoring is showing a clear relationship between abundance and salinity load. Aquatic invertebrate monitoring was largely ceased because population densities were too low and didn't justify the sampling effort. Water level modification/management at Lake Warden was very successful, resulting in lowered salinity concentrations and much higher waterbird abundance (mainly banded stilts) in 2013/14 than in the previous year when water levels were too low. In 2014/15 the aim will be to emulate the 2013/14 water depths and salinity to see if we get same high waterbird abundance. The next step in the project will be to undertake hydrological modelling to determine whether moving excess water (and therefore salt loads) onto Pink Lake is a viable solution to reducing salinity in Lake Warden.

Regional variability in salmon gum communities in the Great Western Woodlands

Scientist

S van Leeuwen

Student

J Harvey

Progress report

This project aimed to determine if there is regional variation in the understorey of *Eucalyptus salmonophloia* woodlands across the Great Western Woodlands (GWW) and, if so, what environmental factors were influencing it. The project then integrated relevant existing survey data from across the Wheatbelt to assess the variation across the two bioregions in which salmon gum woodlands occur, Avon-Wheatbelt and Coolgardie. This project fills large gaps in the floristic surveys of the GWW, which have previously focused on the banded ironstone and greenstone ranges. One hundred sites were sampled in spring 2011 and 2012, in old growth woodlands or woodlands where the timber cutting and/or grazing history could be estimated. Data was collected on species composition, cover and height, tree dimensions, site-based variables, and soil physical and chemical characteristics. Detailed classification and ordination of the data revealed two main communities; one with an understorey of mainly chenopod species on soils higher in clay found in the drier north and east of the GWW, and the

other with non-chenopod species (e.g. *Eremophila* spp., *Acacia* spp., *Scaevola spinescens* and *Alyxia buxifolia*) found on sandier soils in the wetter south and west. Precipitation, monthly precipitation variability and temperature, and to a lesser extent soil phosphorous, pH, silt content, and cover of organic crust influenced the patterns in floristic composition and differentiated between the two main communities. When data from the Wheatbelt was incorporated the two GWW communities remained prominent and were joined by two Wheatbelt communities and one community (with *Melaleuca pauperiflora*) that traversed the two regions. Across this larger area the influence of the annual precipitation gradient and ratio of summer to winter rainfall (less in the east) was strong. Generally regional factors (such as climate) were more influential on the floristic patterns than local (such as soil) factors. This project has contributed to knowledge about these woodlands relevant to their conservation status, delineation of subregional boundaries and land management activities. The salmon gum - chenopod shrublands burn less frequently as they are less flammable and have a more sparse cover than the salmon gum - eremophila woodlands which are experiencing fire more frequently and consequently being reduced in extent. Vouchers for all species collected will be lodged in the Perth Herbarium and the field data will be lodged with TERN-ÆKOS.

Wildlife ecology in the southern jarrah forest

Scientist

A Wayne

Student

G Yeatman

Progress report

The project aims to i) complete a baseline survey of the small terrestrial vertebrates in Perup Nature Reserve; ii) investigate patterns of distribution and abundance of small vertebrates in the southern jarrah forest in relation to habitat; iii) estimate woylie home range size in and outside the Perup Sanctuary; iv) investigate spatial patterns and v) temporal patterns in the distribution of woylies across the Upper Warren Region in relation to habitat.

Progress to date includes the completion of all fieldwork. A report has been completed on the baseline survey of small terrestrial vertebrates and the patterns of distribution and abundance in relation to habitat in the Perup Nature Reserve. Scientific articles relating to broad scale habitat associations of small vertebrates, fine scale vegetation associations of small vertebrates, home range and space use of woylies and spatial and temporal patterns of woylie distribution in the Upper Warren are being submitted for publication.

The role of *Toxoplasma gondii* in declining populations of the woylie (*Bettongia penicillata ogilbyi*)

Scientist

A Wayne

Student

A Worth

Progress report

The aim of this study is to increase understanding of the role of the protozoan parasite *Toxoplasma gondii* in wild woylie populations, particularly with regard to the recent population declines. *Toxoplasma gondii* can infect virtually any warm-blooded vertebrate, and has a worldwide distribution. In asymptomatic laboratory and wild rodents, *T. gondii* is reported to cause subtle changes in behaviour that may make infected hosts more susceptible to predation. In conjunction with the woylie project, we are also investigating mouse behaviour in response to *T. gondii* infection, particularly behaviours related to activity level, anxiety behaviour and cat urine avoidance behaviour.

If *T. gondii* alters the behaviour of woylies, this could predispose infected individuals to predation and increase mortality rates, thus contributing towards the decline of woylie populations. Serum samples collected by Department of Parks and Wildlife staff over the past six years will be analysed to determine *T. gondii* infection status. This will provide insights into the ecology of *T. gondii* infection in woylie populations and an opportunity to investigate whether this parasite alters woylie behaviour by correlating infection status with behavioural attributes. Three posters have been presented on this work at conferences and another is planned for later this year. One scientific journal article and one book chapter concerning the effect of *T. gondii* on host behaviour have been published so far.

An exploration of the associations between the population decline of *Bettongia penicillata ogilbyi* (Gray, 1837) and field health assessment data from the Upper Warren region Western Australia

Scientist

A Wayne

Student

M Pleitner

Progress report

This project will investigate possible associations between the population decline of the critically endangered woylie and the skin and fur conditions found on some individuals. Some woylies show skin alterations accompanied by fur loss. The causes for these changes remain unclear. In this project the data collected in the Upper Warren Region between November 2005 and April 2013 will be evaluated. Changes in the prevalence of these conditions and a possible correlation with survival rates and the population decline will be investigated.

Genetic diversity of *Blastocystis* isolates found in West Australian native fauna

Scientist

A Wayne

Student

U Parkar

Progress report

Prior to this study, limited data was available regarding the prevalence of *Blastocystis* in Australian native fauna. This study determined the prevalence and the genetic diversity of *Blastocystis* in wild native fauna in the south-west region of Western Australia. As part of this study, four species were examined for *Blastocystis* and four different genetic groups (subtypes) were found within these populations. Furthermore, a molecular tool was developed to screen samples for *Blastocystis*, *Giardia duodenalis* and *Cryptosporidium* sp. simultaneously. This multiplex PCR was tested against singleplex PCRs and microscopy. We have found this test to be equally sensitive or to have greater sensitivity than the singleplex PCR, and it has greater sensitivity and specificity than microscopy. Data collation and two publications are currently in preparation.

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

Scientist

A Wayne

Student

S Hing

Progress report

Infectious disease has been suggested as a factor contributing to the recent 90% decline of the woylie, now critically endangered. The effects of infectious disease on woylies may be exacerbated by as yet unknown factors such as stress. This project aims to investigate how stress affects immune function and patterns of infection in the context of endangered species conservation. The hypothesis is: if stress affects immune function and patterns of infection in woylies, we expect changes in immunological variables and patterns of parasite infection with varying exposure to conservation relevant stressors. Endangered species face numerous threats that can constitute stressors that challenge an animals' physiological balance. Stressors to be investigated in this study include predators, resource availability, social interactions, population density and translocation.

Extensive field and laboratory work will be performed to investigate links between stress and disease expression in woylies in the context of their decline. Study populations include captive and free-ranging woylies at Native Animal Rescue, Karakamia Sanctuary, Whiteman Park and the Upper Warren region. Diagnostic and laboratory methods will be applied to conduct parallel evaluation of stress hormones, immune function and parasites in woylies. Data will be used to develop models to improve our understanding of how stress affects the health of endangered wildlife and potential ramifications for species conservation and management.

In the project's first year, intensive sample collection and preliminary analyses has been undertaken and the first paper accepted for publication. Fieldwork, sample collection, laboratory analyses and dissemination of information will continue with support from the Australian Academy of Science Margaret Middleton Fund, Foundation for National Parks and Wildlife and Holsworth Research Endowment.

Diversity of trypanosomes infecting Western Australian marsupials: virulence and pathogenicity

Scientist

A Wayne

Student

A Botero

Progress report

While much is known of the impact of trypanosomes on human and livestock health, trypanosomes in wildlife, although ubiquitous, have largely been considered to be non-pathogenic. This project aimed to investigate the genetic diversity and potential pathogenicity of trypanosomes naturally infecting Western Australian marsupials with particular emphasis on those parasites associated with the endangered woylie (*Bettongia penicillata*). 554 blood samples and 250 tissue samples collected from 50 carcasses of sick-euthanised and road-killed animals, belonging to 10 species of marsupials, were screened for the presence of trypanosomes using a PCR of the 18S rDNA gene. PCR results revealed a rate of infection of 67% in blood and 60% in tissues. Inferred phylogenetic trees using 18S rDNA and glycosomal glyceraldehyde phosphate dehydrogenase (gGAPDH) sequences showed the presence of three different species of *Trypanosoma*: *Trypanosoma copemani*, *Trypanosoma vegrandis*, and *Trypanosoma* sp. H25. *Trypanosoma* infections were compared in a declining and in a stable population of the woylie. High rates of infection with *Trypanosoma copemani* (96%) were found in the declining population, whereas in the stable population, *Trypanosoma vegrandis* was predominant (89%). Mixed infections were common in woylies from the declining but not from the stable population. Histopathological findings associated with either mixed or single infections involving *Trypanosoma copemani* showed pathological changes similar to those seen in *Didelphis marsupialis* infected with the pathogenic *Trypanosoma cruzi* in South America: myocarditis and tongue degeneration. *T. copemani* was successfully grown in culture and for the first time it was demonstrated that this species has the capacity to not only colonise different tissues in the host but also to invade cells in vitro. This study also showed that commercial drugs and new compounds developed against the pathogenic *T. cruzi* are active in vitro against *T. copemani*. These results provide evidence for the potential role of trypanosomes in the decline of the woylie and contribute valuable information towards directing management decisions for endangered species where these parasites are known to be present at high prevalence levels.

This research has been presented at international and national conferences. One paper was published in the *International Journal for Parasitology: Parasites and Wildlife*, and three more papers are in process of submission.

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

Scientist

A Wayne

Student

K Jones

Progress report

Infectious pathogens (e.g., *Trypanosoma* spp.) may play a role the recent >90% declines of the woylie; thus, characterising factors influencing pathogen transmission is a priority and the focus of this project.

Research will occur in two semi-free-ranging populations near Perth (high density Karakamia Sanctuary and Whiteman Park, which will shift from high-to-low density due to enclosure expansion) and in free-ranging woylie populations in the Upper Warren region. At the *community* level, validated methods will be applied to identify and evaluate the prevalence of gastrointestinal and hemopathogens in woylies and sympatric marsupials. Multi-host (vector-borne, where applicable) transmission models will be used to evaluate the contribution of various co-host species to the basic reproductive number (R_0) of targeted pathogens. At the *population* level, woylies at Whiteman Park and Karakamia Sanctuary will be fitted with GPS collars to monitor movements; then social network analysis will be used to map pathogen transmission pathways and their relationship with density. These data will be used to develop networks that reflect potential transmission pathways for contagious, refuge-based, or environmental pathogens. In addition, the effects of translocation will be assessed by looking at members of the donor and recipient woylie populations before, during, and after translocation. Finally, at the *individual* level, screening for pathogens while assessing health, reproduction, and behavioural attributes will allow assessment of risk factors and potential fitness effects of pathogens in isolation or combination. Furthermore, network transmission models can facilitate the identification of behavioural traits (e.g., connectedness) or demographic factors (e.g., age, sex) key to pathogen propagation.

In this first year of the project, collection of field data has begun, with successful sampling at all sites and collar deployment at the two northern sites. Data collection will continue through 2015, as well as initial laboratory and data analysis.

The ecology of parasite transmission in fauna translocations

Scientist

A Wayne

Student

A Northover

Progress report

This project will investigate how fauna translocations impact the transmission of parasites in woylies (*Bettongia penicillata*), and what consequences this has for translocated populations and the recipient host community. As we lack a rigorous understanding of whether current parasite management protocols enhance translocation success, we will also assess the impact of parasite removal on translocated hosts. The information obtained from this research will be incorporated into models that will enable the design of translocation protocols that aim to improve the outcome of native fauna translocations.

For the first translocation, which was successfully completed in June 2014, 181 woylies (90 male and 91 female) were translocated from Perup Sanctuary to two adjacent sites (Walcott and Warrup East). Pre- translocation, woylies from both the source and destination sites were measured and weighed (to

estimate body condition), and pouch activity was recorded for females (to measure reproductive output). Blood, faecal, and ectoparasite samples were also collected for parasitological examination (gross, microscopic, PCR). In both destination sites, sympatric marsupials (brushtail possum - *Trichosurus vulpecula*; chuditch - *Dasyurus geoffroii*) were also sampled so that we are able to quantify parasite transmission between species post-translocation. In order to empirically test whether the removal of parasites from translocated woylies improves host fitness and translocation success, we treated half the woylies (50% male and 50% female) with an antiparasitic drug prior to translocation. To determine the efficacy of this treatment, we will be sampling woylies four and 12 weeks post-translocation (July and September 2014). Monitoring and sampling from both destination sites will continue until 30 months post-translocation. It is expected that data analysis will commence in August 2014.

Trypanosome polyparasitism and the decline of the critically endangered Australian potoroid, the brush-tailed bettong (*Bettongia penicillata*)

Scientist

A Wayne

Student

C Thompson

Progress report

This project focused on investigating the correlation of the trypanosomes found in the blood of woylies and the overall population decline of the host. Trypanosomes in the blood of the woylie can be grouped into three morphologically distinct trypomastigote forms, encompassing two different species; two phenotypes of *Trypanosoma copemani* and one form of the smaller, *Trypanosoma vegrandis* sp. nov. The prevalence of parasitic infections varied among the study sites, with contrasting trypanosome prevalence observed from the two declining indigenous populations within the Upper Warren region in south-west Western Australia. Parasitaemia associated with trypanosome infection in the peripheral blood of the woylie exhibited a temporal decline as the infection progressed, being indicative of the infection transitioning between the acute and chronic phase. *Trypanosoma copemani* also exhibits a predilection for certain tissues of the host, where they can display *Trypanosoma cruzi*-like pathology at the time of autopsy. It appears that the chronic intracellular association of trypanosomes with the internal organs of the woylie may be potentially pathogenic and adversely affect the fitness and coordination of the woylie, making them more susceptible to predation, and contributing to the overall decline. Three scientific papers have been published, and one is in preparation.

Histopathological review of the causes of death in Woylies (*Bettongia penicillata*) presented to Murdoch University for necropsy in the last 10 years, with special focus on (possible) *Trypanosoma* related histopathology.

Scientist

A Wayne

Student

Z Lim

Progress report

The aim of this project is to review the causes of deaths and histopathology in the woylies presented to Murdoch University in the last 10 years; with special attention dedicated to detecting the presence of Trypanosomes, their related histopathology and their significance. So far, two Woylies out of the (approximately) 50 have been identified to have organisms (morphologically similar to Trypanosomes) in association with muscle lesions in the oesophagus and heart. These muscle lesions may have potentially resulted in decreased food intake and abnormal function of the heart respectively; with possible contribution to the death of the individual. This project will also attempt to identify the Trypanosomes and demonstrate spatial association between *Trypanosoma* DNA and muscle (or other) lesions via the use of in-situ hybridization. In light of the recently published study by Botero et al.

(2013), an increased understanding of the effects of *Trypanosoma* infections in the woylie will help aid the future management of this declining species.

A database has been developed that collates post-mortem results from woylies, including tissues examined (and findings) and tissues held in archive. The database is almost complete. The findings will be reviewed and collated. Additionally, various probes have been designed for use in *in-situ* hybridisation for the detection of protozoal DNA in tissue sections. Six probes have been designed and purchased, to include *Sarcocystis*, *Trypanosoma* and *Toxoplasma* organisms. Labelling efficiency tests will start June/July 2014, with trial runs on tissues from quolls, in partnership with a separate project.

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

Scientist

A Wayne

Student

K Skogvold

Progress report

This project investigates if disease is a significant factor in the declines and lack of recovery of the woylie. Comparisons are made over time of the health and disease of woylies in three varying population management systems - wild, predator-free sanctuary and captive. Sampling from the Perup Sanctuary gives the opportunity to investigate and focus on the role of disease in the absence of introduced predators.

Health testing at these sites has been completed and included haematology, biochemistry, gastrointestinal parasite load, anti-oxidant and vitamin levels, and determination of stress levels using hair, faecal and serum cortisol. Screening for significant marsupial pathogens and diseases has included haemoparasites, toxoplasmosis and selected viruses (Wallal & Warrego orbiviruses and macropodid herpesviruses). Significant progress has been made in the data analysis and writing up phases. Reference ranges for haematology and serum biochemistry are being established, and a journal paper on the findings of herpesvirus screening is underway.

Ecological study of the quokka (*Setonix brachyurus*) in the southern forests of south-west Western Australia

Scientist

A Wayne

Student

K Bain

Progress report

This project aims to: i) determine if a reliable estimate of quokka abundance can be obtained from indicators of activity including scats, tracks and runnels; ii) identify the preferred habitat of quokka in southern forests; iii) determine the mobility and activity patterns of quokka in the southern forests; iv) identify the influence of fire on distribution and abundance of quokka in the southern forests; and v) in collaboration with others determine whether the sub-populations constitute a functional meta-population. Occupancy models were generated from presence/absence data and have identified the density of the near-surface fuel layer, vegetation structure and proximity to a different fuel age as the subset of variables that best predict the probability of occupancy of habitat by quokka. Associated monitoring by cage and camera trapping indicates that feral cats were responsible for almost complete recruitment failure over a four year period due to predation of young immediately after pouch emergence.

Home range and movement patterns have been investigated using 29 collared quokkas and results indicate a mean home range of 71ha (core range 18ha) with movements averaging between 0.4 and

2.4km/night. Largest movements were recorded in summer and autumn and were linked to requirements to forage further afield for water and food during hot dry conditions. Collared animals spent 40% of their time in riparian habitat within a stable home range and emigrating individuals travelled distances of up to 14.2km, using riparian vegetation as corridors. Forest areas with fire treatment and comparable unburnt sites have been examined for quokka abundance and habitat quality pre- and post-fire to determine the effect of fire on habitat use and the time taken for habitat to become re-colonised post-fire. DNA has been provided to staff at Murdoch University, who will be assisting with DNA processing. A paper presenting an effective and efficient survey method for quokka has been published.

Ectoparasites of threatened mammals in Western Australia: biodiversity and impact

Scientist

A Wayne

Student

H Burmej

Progress report

This project aims to investigate the biodiversity and ecological impact of ectoparasites across a range of threatened mammalian hosts in Western Australia. Mammals from diverse environments including islands, south-western forests and semi-arid regions were sampled in different seasons from 2006 to 2010. The ectoparasite fauna from a variety of threatened mammalian species were sampled and in most cases identified to species level using existing keys. A literature review was conducted and new host-parasite lists constructed for animals including woylies and boodies (*Bettongia* species), *Rattus fuscipes*, quenda (*Isoodon obesulus*), golden bandicoot (*Isoodon auratus*) and common brushtail possum (*Trichosurus vulpecula*). A putative new species of *Ixodes* tick found on the woylie was examined using light microscopy and Scanning Electron Microscopy. Ticks and fleas were examined using molecular methods for the presence of Trypanosomes (in an effort to identify the arthropod vector for Trypanosomes found in woylies and other mammals), but none were found.

Assessing the resilience of marine turtle embryos to extreme temperatures

Scientist

S Whiting

Student

J Tedeschi

Progress report

This project is designed to investigate the resilience of sea turtles in relation to climate change. Sea turtles are reliant on relatively narrow temperature ranges for incubation of eggs and also sex determination of the embryos. Higher or lower temperatures can lead to mortality of the embryos and changes within these ranges can lead to sex biases. Variation within and between turtle species will be determined through gene expression in temperature-sensitive genes. A major objective is to determine if the differential expression of specific genetic markers can be used as proxies for estimating the tolerance of marine turtle embryos to extreme temperatures. More specifically, this project will investigate whether there is phenotypic variation within and between species, and at what pace thermal tolerance may evolve. The work will primarily be undertaken on flatback turtles and loggerhead turtles. Field work for this project has been completed and data is being analysed.

The nesting and post-nesting ecology of hawksbill turtles in northern Australia

Scientist

S Whiting

Student

X Hoenner

Progress report

This project investigated the nesting ecology and post-nesting migration phase of hawksbill turtles in the Northern Territory, using on-ground surveys and satellite telemetry at Groote Eylandt. Specific aspects of the project involved estimating the size of the annual nesting population, determining nesting seasonality, assessing mortality on the beach, mapping inter-nesting habitat and post-nesting migration routes and describing dive behaviour and in-water habitat use.

This project has extended our understanding of hawksbill turtle biology and ecology in the areas of nesting biology, identification and description of critical habitats during the inter-nesting, post-nesting and foraging phases of life history, and understanding migration and diving behaviour. It was confirmed that Groote Eylandt is a nationally significant rookery for hawksbill turtles and previously unidentified foraging habitat in the Gulf of Carpentaria was identified. This project is now completed. One paper has been published and three more are to be submitted.

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

Scientist

S Whiting

Student

B Bentley

Progress report

This project is part of the WAMSI Kimberley Node Turtle Project, and will investigate climate change impacts on turtle nesting using prediction and hind-casting models. It will investigate pivotal temperatures for green and flatback turtles using laboratory incubation experiments and investigate sex ratios of wild populations in the field. So far permit applications have been written, literature searches are under-way and planning for the 2014 field trips has been completed.

Assessing the resilience of marine turtle embryos to extreme temperatures

Scientist

S Whiting

Student

J Stubbs

Progress report

This project investigated the effect of temperature on turtles at Cape Domett beach in the eastern Kimberley. The major findings of this project included the determination of a pivotal temperature (the incubation temperature at which 50% males and 50% females are produced) for a winter/dry season nesting population of flatback turtles and the development of predictive climate models based on measured and hind-cast data. The results of this work have been submitted for publication in a peer reviewed journal.

Optimal release locations and timing for rehabilitated sea turtles using a decision support system

Scientist

S Whiting

Student

N Robson

Progress report

This project aims to identify the most suitable locations and months to release rehabilitated turtles along the Western Australian coast. The project will primarily use an ocean current model developed through the University of Western Australia to run dispersal models under a range of scenarios and assess the probability of released turtles reaching suitable oceanic neonate habitat. A qualitative decision process will then be used to select the most appropriate release locations based on cost, travel time and accessibility. The end result will be a decision support tool that can be used by the Department of Parks and Wildlife staff to assess timing and locations of future releases.

How does a seaweed-associated reef fish respond to seasonal habitat loss?

Scientist

S Wilson

Student

I Lim

Progress report

Habitat-dependent species may undergo sudden collapse in populations as a result of dramatic declines in habitat availability or quality. At Ningaloo Reef, the marbled parrotfish fish, *Leptoscarus vaigiensis*, predominantly associates with seaweed habitats, which represent a substantial portion of shallow water benthos, both at Ningaloo and along the tropical WA coast. These seaweed habitats undergo dramatic seasonal changes in structure, and there are likely to be periods when *L. vaigiensis* experiences low habitat availability. This project will assess how dependent *L. vaigiensis* is on seaweed for habitat/ diet, and the consequences of seasonal shifts in seaweed on *L. vaigiensis* population dynamics. The project will improve understanding of factors that influence the distribution and abundance of species that have key functional roles within the extensive seaweed fields along the Western Australian coast. Surveys of fish abundance and seaweed structure were undertaken at 10 sites in summer 2014 and will be repeated in the winter

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

Scientist

S Wilson

Student

J Goetze

Progress report

The overall aim of this study is to determine whether periodically fished areas (tabu) can successfully protect locally targeted reef fish assemblages and how the intensity of harvest events impacts on their effectiveness. To do this, a large-scale empirical study will focus on testing variation in the intensity that tabu areas are harvested. Using the results from this study and others in the region, a meta-analysis will be done that will examine whether tabu areas are a successful fisheries management tool that can provide a viable alternative to permanent marine reserves by either maintaining or increasing local fish stocks. This information will assist with the formation of a set of guidelines that provide advice to local communities on how to manage these tabu areas.

Field work on this project is almost completed. A manuscript assessing which survey techniques best detected impacts of harvesting has been submitted for publication. Funding for a workshop on meta-analyses has been secured and will be run in January 2015.

Quantifying the role of mesopredatory fish in coral reef food webs

Scientist

S Wilson

Student

E Thillainath

Progress report

Coral reefs are diverse, complex environments that support a wide array of fish assemblages and associated sea-scapes. Identifying the functional role of fish and understanding how they interact with other species is critical for the effective management and conservation of reef systems. Coral reef meso-predators maintain and regulate ecosystem dynamics, although it is often difficult to identify explicit trophic links between species due to the exceedingly complex nature of marine food webs. Consequently, the function of predators and meso-predators in coral reef ecosystems is often not apparent, and can be difficult to distinguish and define. By expanding our understanding of the functional and trophic role of meso-predators on coral reefs, we can predict not only their response to external factors such as climate change and overfishing, but their contribution to trophodynamics and energy flow in the ecosystem. Using an integrated approach, the project calculated turnover rates of several species of meso-predatory fish at Ningaloo Reef, providing estimates of how important these fish are in local food webs.

Quantitative diet analysis of four mesopredators from Ningaloo Reef, Western Australia

Scientist

S Wilson

Student

E Ashworth

Progress report

The functioning of fish assemblages rests mainly on the trophic status of species. Gut content analyses provide insight into feeding behaviours and lead to better understanding of the complex interactions between fish species. Mesopredators are common on coral reefs and fluctuations in their abundance may influence prevalence of prey. However, there is a lack of information on mesopredator diets, making it difficult to assess how changes in their abundance will influence prey, reef trophodynamics and ecology.

This study examined the gut content of four mesopredator species: *Epinephelus rivulatus*, *Parapercis clathrata*, *Pseudochromis fuscus* and *Synodus dermatogenys*. Mobile benthic invertebrates, particularly decapods, were the main item in the diet of three mesopredator species. However, one species, *S. dermatogenys*, fed exclusively on other fish species. A manuscript based on this work has been published in the *Journal of Fish Biology*.

Climate change impacts on the northern sandplain kwongan vegetation of south-western Australia

Scientist

C Yates

Student

A Williams

Progress report

On-going climate change through the 21st century projects increasingly warmer and drier conditions for Mediterranean type ecosystems (MTEs), creating threats to species persistence in these biodiversity hotspots. For the highly biodiverse kwongan of south-west Australia, this means a climate shifting

towards semi-arid conditions, yet how this unique vegetation type will respond to a novel hotter and drier climate is largely unknown. Therefore, this study examined the effects of altered rainfall and temperature on demographic processes of woody kwongan in post-fire (0-3 years since last fire) and mature (12 - 15 years since last fire) stands across a soil depth gradient in the northern sandplains of south-western Australia, seeking to identify the consequences for plant species and functional trait composition. To achieve this, a selection of commonly occurring species (*Banksia attenuata*, *Banksia hookeriana*, *Melaleuca leuropoma* and *Beaufortia elegans* as primary focal species) were used to form a plant functional trait scheme, with fire-response strategy (resprouter, non-resprouter) as a trait of key interest due to the fire prone nature of MTEs, and leaf type (broad, needle, small), growth form (shrub, subshrub) and seed size (large, medium, small) as traits of interest due to their potential roles in drought and temperature responses. Passive rainout shelters were used to reduce rainfall, and drip irrigation to increase rainfall, by ~30 %. Open top chambers were used to increase temperature, with daytime temperature increased by an average of 2.9°C.

Seedling germination, survival and growth, and adult survival, health, flowering and fruiting were reduced by drought and warming, with increased rainfall producing little change. Greater magnitude of reduction was observed under experimental warming, however experimental drought resulted in greater degree change in functional trait composition. Despite the general higher resistance of adult resprouters, it was non-resprouters that showed potential to become the dominant fire-response strategy in a drier environment, through higher seedling resilience and similar resistance as adults to resprouters. With a decline in survival for both post-fire resprouts and seedlings, resprouters could be at risk of population decline in the long term. Subshrub and small leaf traits were the most successful in drought conditions due to their drought tolerant nature, while broad leaf and shrub traits will likely suffer population decline. In warmer conditions, significant decline in resprouter seedling survival was matched by equally large decline in non-resprouter adult survival, indicating little change in dominance of non-resprouters at the seedling stage and resprouters at the adult stage, and thus little change in their relative abundances. The needle leaf trait was most competitive in warmed conditions performing well relative to other traits both in seedlings and adults. Shallow soil profiles, reflecting lower water availability, negatively affected demographic rates, suggesting decreases in diversity and density on shallow soils as less drought tolerant species retreat to deeper soil profiles with greater water stores.

Results here show potential for large scale change in MTEs in projected warmer and drier climates, through decline in vulnerable functional traits, and thus reduced density of woody species and losses to biodiversity. Further investigation is needed into the combined effect of warming and drought, in addition to impact of altered fire regime, with changes in fire behaviour projected for MTEs as a result of warmer and drier conditions. Investigation that encompasses a broader range of Mediterranean species is also necessary to provide greater accuracy to conclusions drawn here on functional trait responses.

Population variation in seed and seedling traits along a climate gradient in south-west Western Australia

Scientist

C Yates

Student

A Cochrane

Progress report

This thesis explored variation in commonly measured functional traits in populations of congeneric species (*Banksia baxteri*, *B. coccinea*, *B. media* and *B. quercifolia* R.Br.:Proteaceae) along a rainfall gradient in south-western Australia. A series of empirical studies examined the response of seed and seedlings of these obligate-seeding species to heat and/or drought stress. These investigations demonstrated the species- and population-specific nature of plant responses to gradients of environmental change. Some common responses occurred across experiments: cross-species patterns generally upheld along the gradient, but decoupling of patterns occurred at the local level. Against expectations, population variation was not reliably associated with geographical location on the rainfall gradient, suggesting that selection for local adaptation in response to water availability or other climate factors has been minimal. Nonetheless, species expressing phenotypic variation along

environmental gradients may have greater capacity to respond to global change. The PhD has been submitted.

