

Science Division annual research activity report and management implications 2012–2013



DIRECTOR'S MESSAGE

The Department has primary responsibility for protecting and conserving the state's natural assets on behalf of the people of Western Australia. Western Australia is a large state with unique biological diversity including internationally recognised terrestrial and marine biodiversity hotspots, 12 internationally significant wetlands and eight of the 15 national biodiversity hotspots. We have a large number of national parks and nature reserves that protect biodiversity and provide superb natural environments for community recreation. Integrated scientific and management expertise is essential in order to provide the depth of knowledge required to effectively manage these complex and diverse ecological systems. While knowledge in other sectors can be obtained from national and international spheres, the explicit knowledge required to manage Western Australia's unique environments and natural assets requires local expertise.

Investment in strategic research develops the understanding, capacity and innovation necessary to identify and respond to emerging issues before they develop into major environmental pressures that impinge on conservation and sustainable development, and have costly long-term impacts on the environment, the community and the economy. Environmental research is a critical activity that supports the Western Australian economy through the mining, agricultural, oil and gas, urban development and tourism industries. Scientific information is required to value the natural assets of the state and to effectively and efficiently manage those assets for the benefit of all Western Australians. Scientific knowledge creates tourism opportunities and enables community enjoyment of our unique natural environments while supporting management of these areas for future generations.

A coordinated science and research capacity integrated with policy and management functions is a strength of the department, and reflects the vital role of science and information in conserving the state's biodiversity and managing its natural assets. An expert science capability embedded in the agency has significant benefits including:

- end-user, risk-based priority setting and funding allocation processes that ensure investment in research is relevant to Western Australia, and that it is feasible, beneficial, cost effective and directly linked to government needs;
- rapid incorporation of up-to-date knowledge to support the department's immediate policy and operational requirements through effective and efficient technology transfer and research up-take;
- the ability to undertake vital strategic long term science essential for government decision making;
- availability of science based knowledge and information to provide accurate and timely scientific, technical and policy advice to government.

The department's internal research capacity is extended and leveraged through attracting external investment to address state priorities, and through strategic collaborations and partnerships with external research agencies and end-users where this provides access to relevant expertise.

There is a clear need for substantial levels of research for effective management of our natural assets, but the resources to carry out such research are limited. This reality necessitates rigorous priority setting and efficiency of operations. The department undertakes this through a risk-based process where research priorities are driven by government and legislative obligations and strategic planning processes. The immediate, broader and longer-term benefits of investment in science are maximised through a departmental Science Policy.

In 2007 the Science Division prepared *A Strategic Plan for Biodiversity Conservation Research* for the 10-year period 2008–2017. In early 2013 the Science Management Team reviewed progress on the first five years of the strategic plan. It is very pleasing to see major progress against actions identified under the five key strategic goals that cover (1) understanding the composition of and patterning in biodiversity, (2) understanding the threats to biodiversity and developing options for amelioration, (3) monitoring condition and trends in ecosystems, (4) providing scientific concepts and tools for best practice management, and (5) improving knowledge of how people respond to and interact with the natural environment.

I can only highlight here a few of the many achievements completed over the past five years. We have undertaken planning processes to guide terrestrial and marine biological survey, plant taxonomy, and plant molecular genetics research and survey to provide an informed basis for management decisions. We developed major understanding of the biology of the Pilbara region and Kimberley Islands through biological survey. We have undertaken a large number of plant and animal translocations to improve the conservation status of threatened species, including doubling the number of individuals of Gilbert's potoroo—Australia's rarest mammal—and establishing five mammals at the Lorna Glen Rangelands Restoration site. We have exceeded the global conservation targets for translocations of threatened plants and germplasm collections.

The FORESTCHECK monitoring program completed two rounds of five-yearly monitoring and a full analysis of the first round provides a baseline on which to assess change. We have completed investigations into the effects of timber harvesting activities on forest ecosystems as required under the *Forest Management Plan 2004–2013*.

We developed a departmental Science Policy that was endorsed by Corporate Executive in 2011 and guides science activities across the department. We established the Western Australian Conservation Science Centre and further developed our partnerships and collaborations with academia, industry and community groups. We are a foundation partner in the Western Australian Biodiversity Science Institute and have engagement with the Western Australian Marine Science Institution. A review of publications showed an 86% increase over the five year period 2006–2011, demonstrating increased effectiveness in communication.

The main actions to achieve further progress in implementing the key strategic goals for the next five years from 2013–2017 have been articulated in a revision of the strategic plan.

The scientific work of the Division that has led to the achievements made over the past five years is a credit to all staff, including scientists and technical officers, and would not be possible without the efficient support of the administrative staff, the work centre managers and library staff. I thank all staff for their ongoing dedication to undertaking and supporting science and research to underpin conservation of Western Australia's unique natural assets. I also take this opportunity to honour the memory of past Director General, Keiran McNamara, who provided great leadership in the application of science to conservation policy and operation.

At the end of June 2013, the Department of Environment and Conservation ceased and the conservation aspects of our business will now continue with renewed focus under the strategic directions of the Department of Parks and Wildlife. I look forward to continuing to provide excellent world-class science and research to support the work of the new department in protecting, managing and enhancing Western Australia's natural assets.

Dr Margaret Byrne
Director Science
June 2013

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VISION

We envisage a society where scientific enquiry is highly respected and forms an objective basis for environmental decision making and policy development.

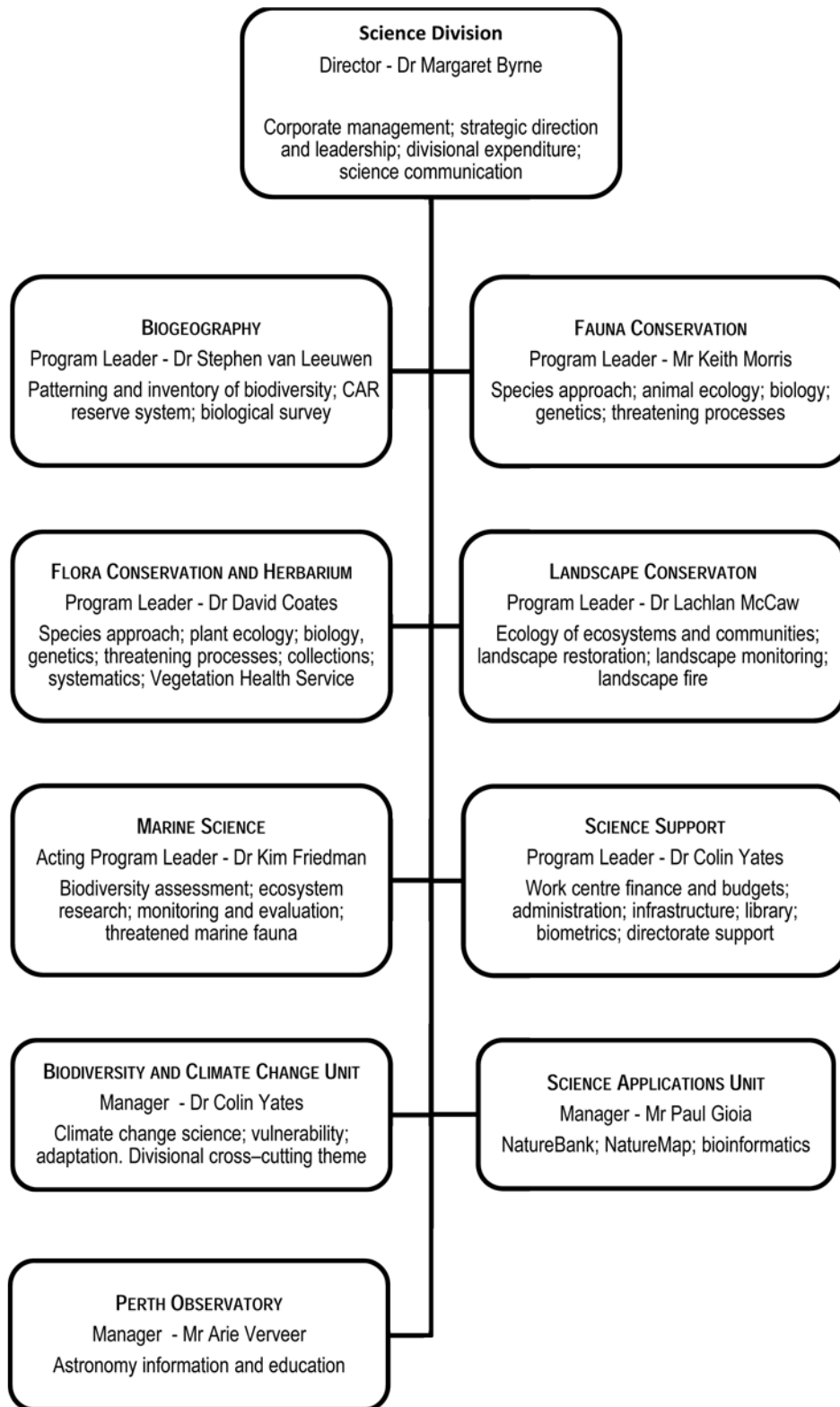
FOCUS

Provision of up-to-date and scientifically sound information to uphold effective conservation of biodiversity and sustainable natural resource management in Western Australia. We strive to provide excellence in science and technology based on internationally recognised best practice. We operate research centres that foster, promote and reward creativity and innovation.

ROLE

- To provide a scientifically objective and independent source of reliable knowledge and understanding about conserving species and ecological communities in Western Australia, managing the public lands and waters entrusted to the Department of Environment and Conservation (DEC), and carrying out DEC's other legislative responsibilities.
- To ensure that Science Division is responsive to the needs of policy makers and end users in DEC by bringing science to bear on the solution of the state's most pressing problems relating to conservation and land management.
- To work in partnership with DEC managers, research institutions and the broader community to increase knowledge underpinning conservation and land management in Western Australia.
- To advise DEC on sustainable resource development opportunities and to promote the conservation of biological resources through their sustainable utilisation.
- To communicate and transfer to managers in DEC, and to the broader community, knowledge, information and other insights obtained through scientific investigation in Western Australia and elsewhere.
- To attain a worldwide reputation for excellence in science by publishing knowledge obtained through scientific research in premier national and international scientific journals and through electronic means.
- To contribute, as an integrated part of DEC, to meeting the need for knowledge on conservation and land management matters by the public of Western Australia.
- To undertake and participate in astronomy research, information and education for the benefit of local, national and international communities.

SERVICE DELIVERY STRUCTURE



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CURRENT COLLABORATION WITH ACADEMIA (STUDENT PROJECTS)

DEC Officer	Student	Project Title	Degree / Level	Duration	University Academic	University
Abbott, Ian	P Van Heurck	The compositional, structural, and functional succession of beetle communities in habitat mosaics created by three different fire regimes in the southern forests of Western Australia	PhD	2005–2012	Prof J Majer	Curtin University
Algar, Dave	A Coddou	Baiting effectiveness for introduced rats (<i>Rattus</i> sp.) on Christmas Island	Hons	2012	Dr H Mills	The University of Western Australia
Algar, Dave	M Johnston	Development of Curiosity feral cat bait	PhD	2012–2014	Dr D Whisson	Deakin University
Algar, Dave	G Hayes	Dietary study of feral cats (<i>Felis catus</i>) and black rats (<i>Rattus rattus</i>) to determine predatory impact and identify bait preference for use in a rat eradication program	Hons	2012	Dr H Mills	The University of Western Australia
Algar, Dave	Low Bing Wen	Black rats in paradise: abundance and home range size on Christmas Island	Hons	2012	Dr H Mills	The University of Western Australia
Algar, Dave	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
Algar, Dave	K Koch	Genetic diversity and phylogeography of Australian cats	PhD	2009–2012	Dr K Schwenk	Johann Wolfgang Goethe University
Burbidge, Allan	C Polson-Brown	The value of remnant and revegetated woodland on Rottneest Island to the red-capped robin (<i>Petroica goodenovii</i>) and golden whistler (<i>Pachycephala pectoralis</i>)	Hons	2012–2012	R Davis	Edith Cowan University
Byrne, Margaret; Coates, David	H Nistelberger	Ancient, terrestrial islands in a semi-arid landscape: patterns of genetic diversity in regional endemics of the Yilgarn Banded Iron Formations	PhD	2010–2013	Dr D Roberts	The University of Western Australia
Byrne, Margaret	J Moniodis	The genetics, essential oil composition and factors	PhD	2010–2013	Dr J Plummer, Dr L Barbour	The University of Western

DEC Officer	Student	Project Title	Degree / Level	Duration	University Academic	University
		controlling the biosynthesis of sesquiterpenes in Western Australian sandalwood				Australia
Coates, David	C Allen	Factors that affect seedling establishment and the implications for the translocation of species at risk of extinction	PhD	2010–2013	A/Prof P Poot, A/Prof M Moody, A/Prof R Standish	The University of Western Australia
Farr, Janet	K Ironside	Trophic dynamics of predatory invertebrates in jarrah forests of differing fire history	MSc	2006–2013	Dr J Prince, Dr P Grierson	The University of Western Australia
Field, Stuart	J Turner	Monitoring coral size-frequency distribution, an investigation into digital methods	MSc	2012	Prof N Polunin	University of Newcastle
Friedman, Kim	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?	Hons	2012–2013	Dr M O'Leary	Curtin University of Technology
Friend, Tony	J Austen	Trypanosomes of some Western Australian mammals: phylogenetics	PhD	2006–2012	Dr U Ryan	Murdoch University
Friend, Tony	J Pridham	Finding a dietary surrogate for the Critically Endangered Gilbert's potoroo <i>Potorous gilbertii</i>	Hons	2012	Dr P Speldewinde	The University of Western Australia
Gosper, Carl	B Lake	Fire regime responses of biological soil crusts in eucalyptus woodlands of south-west Australia	Hons	2013	P Grierson	University of Western Australia
Huisman, John	R Dixon	Systematics of <i>Sargassum</i> (Phaeophyceae) in Australia	PhD	2008–2012	Dr J Huisman	Murdoch University
Keighery, Greg	T Hevroy	Molecular taxonomy, phylogeography and population genetics of the <i>Grevillea thelemanniana</i> complex	PhD	2010–2012	Asst Prof M Moody (Texas), S Krauss (BGPA)	The University of Western Australia
Kendrick, Alan; Wilson, Shaun	A Turco	The role of <i>Kyphosus</i> spp. in reef ecosystems	PhD	2012–2015	Assoc Prof G Hyndes	Edith Cowan University
Kendrick, Alan	F Vitelli	Feeding ecology of Pomacentridae and its ecological role in fish herbivory in temperate	MSc	2012–2013	Assoc Prof G Hyndes	Edith Cowan University

DEC Officer	Student	Project Title	Degree / Level	Duration	University Academic	University
		algal-dominated reefs				
Macfarlane, Terry	IA Raheem	Systematic and evolutionary studies of the eastern and southern Australian clade of the genus <i>Hibbertia</i> Andrews subgenus <i>Hemistema</i> (Thouars) JW Horn	PhD	2009–2012	Dr JG Conran	University of Adelaide
McCaw, Lachie	M Peace	Fire weather	PhD	2010–2013	Dr T Mattner, Dr G Mills, Dr J Keppert	Adelaide University, Centre for Australian Weather and Climate Research
Morris, Keith	K Bettink	Ecology and taxonomic differentiation in the Australian water rat and implications for its conservation status in Western Australia	MSc	2010–2014	Dr H Mills	The University of Western Australia
Morris, Keith	R Thavornkanlapachai	Genetic consequences of mammal translocations in Western Australia using case studies of dibblers, boodies and black-flanked rock wallabies	PhD	2011–2014	Dr H Mills	The University of Western Australia
Morris, Keith	J Dunlop	Factors affecting fauna translocation success	PhD	2010–2013	Prof A Thompson	Murdoch University
Pinder, Adrian	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	R Vogwill	The University of Western Australia
Pinder, Adrian	D Quek	Breeding systems and phylogeography of selected saline lake invertebrates	Hons	2013	J Chaplin	Murdoch University
Radford, Ian	Ian H McGregor	Mammal declines in northern Australia: science for conservation and recovery	PhD	2010–2014	Prof C Johnson	University of Tasmania
Radford, Ian	G Daniel	Kimberley remote sensing vegetation structure	MSc	2011	Prof L Mucina	Curtin University
Robinson, Richard	F Tovar	Fungi causing decay in coppiced bluegum stumps	PhD	2006–2012	Dr T Burgess, Dr G St J Hardy	Murdoch University
Shearer, Bryan	P Staskowski	Mechanisms of phosphite action	PhD	2006–2011	Dr G Hardy	Murdoch University
Simpson,	A Hill	Factors influencing the	PhD	2008–	Dr S Shea	Notre Dame

DEC Officer	Student	Project Title	Degree / Level	Duration	University Academic	University
Chris		establishment of marine protected areas in Western Australia		2011		University
Stukely, Mike	A Rea	Classical and molecular taxonomy and pathogenicity testing of <i>Phytophthora</i> species	PhD	2007–2012	Dr G Hardy	Murdoch University
Stukely, Mike	A Simamora	Multiple new <i>Phytophthora</i> species from Western Australia: taxonomy, pathogenicity and disease control	PhD	2011–2014	Prof G Hardy, Dr T Burgess	Murdoch University
van Leeuwen, Stephen	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
Wayne, Adrian	K Zosky	Food resources and woylie declines in south-west Western Australia	PhD	2007–2012	Dr K Bryant, Dr M Calver	Murdoch University
Wayne, Adrian	A Worth	The role of <i>Toxoplasma gondii</i> in declining populations of the woylie (<i>Bettongia penicillata obiby</i>)	PhD	2011–2013	Prof A Thompson	Murdoch University
Wayne, Adrian	G Kaewmongkol	<i>Bartonella</i> infections in wildlife and domestic animals in Western Australia	PhD	2010–2012	Dr S Fenwick	Murdoch University
Wayne, Adrian	Y Abdad	Rickettsial infections in wildlife and humans in Western Australia	PhD	2006–2012	Dr S Fenwick	Murdoch University
Wayne, Adrian	A Botero	Diversity of trypanosomes infecting Western Australian marsupials: virulence and pathogenicity	PhD	2013	Prof A Thompson	Murdoch University
Wayne, Adrian	U Parkar	Genetic diversity of <i>Blastocystis</i> isolates found in West Australian native fauna	PhD	2013	Prof A Thompson	Murdoch University
Wayne, Adrian	K Skogvold	A comparative health and disease investigation in the woylie: captive vs free-range enclosure vs wild	PhD	2011–2013	Dr K Warren, Dr S Vitali, Dr C Holyoake, Dr C Monaghan	Murdoch University
Wayne, Adrian	C Thompson	Trypanosome polyparasitism and the decline of the critically endangered Australian potoroid, the brush-tailed bettong (<i>Bettongia penicillata</i>)	PhD	2010–2013	Prof A Thompson	Murdoch University

DEC Officer	Student	Project Title	Degree / Level	Duration	University Academic	University
Wayne, Adrian	G Yeatman	Wildlife ecology in the southern jarrah forest	PhD	2011–2014	Dr H Mills	The University of Western Australia
Wayne, Adrian	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, Ass Prof A Lymbery, Dr T Fleming	Murdoch University
Wayne, Adrian	S Pan	<i>Toxoplasma gondii</i> infection and atypical genotypes in Western Australian wildlife species	PhD	2008–2012	Prof A Thompson	Murdoch University
Wayne, Adrian	H Burmej	Ectoparasites of threatened mammals in Western Australia: biodiversity and impact	PhD	2007–2012	Prof A Thompson, Dr A Smith	Murdoch University
Wayne, Adrian	K Bain	Ecological study of the quokka (<i>Setonix brachyurus</i>) in the southern forests of south-west Western Australia	PhD	2006–2013	Assoc Prof R Bencini	The University of Western Australia
Whitford, Kim	E W Smithers	Ecosystem carbon dynamics in bauxite mining in jarrah (<i>Eucalyptus marginata</i>) forests in south-western Australia	MSc	2011–2012	Prof R Harper	Murdoch University
Whiting, Scott	J Tedeschi	Assessing the resilience of marine turtle embryos to extreme temperatures	PhD	2011	Assoc Prof N Mitchell, Dr J Kenington, Dr S Whiting, Dr O Berry, Dr M Meekan	The University of Western Australia, Australian Institute of Marine Science, CSIRO
Whiting, Scott	X Hoenner	The nesting and post-nesting ecology of hawksbill turtles in northern Australia	PhD	2009–2012	Dr C McMahon Dr S Whiting	Charles Darwin University
Wilson, Shaun	E Thillainath	Quantifying the role of mesopredatory fish in coral reef food webs	Hons	2013	Dr J McIlwain	Curtin University
Wilson, Shaun	J Goetze	Variation in the intensity of periodic harvests in Fijian tabu areas and the effect on reef fish assemblages	PhD	2012–2015	E Harvey	The University of Western Australia
Wilson, Shaun	E Ashworth	Quantitative diet analysis of four meso-predators from Ningaloo Reef, Western Australia	MSc	2012	Dr D Banaru	Aix-Marseille University, France
Yates, Colin	A Williams	Climate change impacts on the northern sandplain kwongan vegetation of	PhD	2010–2013	Dr N Enright	Murdoch University

DEC Officer	Student	Project Title	Degree / Level	Duration	University Academic	University
		south-western Australia				
Yates, Colin	A Cochrane	Population variation in seed and seedling traits along a climate gradient in south-west Western Australia	PhD	2010–2013	Dr A Nicotro, Dr G Hoyle	Australian National University

EXTERNAL PARTNERSHIPS

Partnership name	Project Title	External Funding	DEC Involvement
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, Curtin University, The University of Western Australia, Saskatchewan University, Royal Botanic Gardens Kew, AAMHatch	Protecting the safe havens: will granite outcrop environments serve as refuges for flora threatened by anthropogenic climate change?	\$330K 2009–2012	C Yates, M Byrne
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, 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, 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, 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 (Abydos Project Offset)	Investigating the interactions between feral predators in the Pilbara	\$200K	K Morris, S van Leeuwen
Atlas Iron (Abydos Project Offset)	Implementing high priority actions derived from the Chichester subregion strategic weed assessment	\$150K	S van Leeuwen
Atlas Iron (Abydos Project Offset, Woodinga Offset), Fortescue Metals Group (Solomon Mine Offset)	Ecology and management of northern quoll in the Pilbara	Atlas: \$100K, \$50K (2010–2016), Fortescue: \$100K (2012–2021)	K Morris, S van Leeuwen, A Cook
Atlas Iron (Mt Dove Offset), CSIRO Ecosystem Sciences	Strategic weed assessment for the Chichester subregion of the Pilbara	\$100K	S van Leeuwen
Atlas Iron (Mt Dove Offset)	Ecology and management of the Pilbara leaf-nosed bat	\$240K	S van Leeuwen, L Gibson, K Morris
Atlas Iron	Sponsorship of the 'Research directions for Pilbara leaf-nose bat' workshop	\$10K	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	DEC Involvement
Australian Biological Resources Study via Adelaide and Murdoch Universities	Marine benthic algae of the Great Barrier Reef	ABRS: \$14K p.a. 2009–2011	J Huisman
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 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 Institute of Marine Science	Coral reef fish recruitment study	AIMS funded field trip	S Wilson, T Holmes
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, Fortescue Metals Group (Cloudbreak Stage B Mine Offset)	Floristic survey of the Fortescue Marsh	\$45K, \$200K	S van Leeuwen, M Lyons, A Markey
BHP Billiton Iron Ore	Ecology and management of Pilbara olive python in the Pilbara	\$50K	D Pearson, S van Leeuwen
BHP Billiton Iron Ore	Identification Botanist position at the Western Australian Herbarium	\$105K	K Thiele
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, 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 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

Partnership name	Project Title	External Funding	DEC Involvement
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, A Burbidge
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	A Burbidge
CSIRO, Edith Cowan University, University of Tasmania	Climate-resilient vegetation of multi-use landscapes: exploiting genetic variability in widespread species	NCCARF \$298K 2011–2013	M Byrne
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
Cazaly Iron Ore Pty Ltd, Botanica Consulting	Assessment of genetic processes in <i>Lepidosperma</i> sp. Parker Range and <i>Lepidosperma</i> sp. Mt Caudan	\$298K 2012–2013	M Byrne
Central Desert Native Title Service	Biological survey of the Birrilburru Indigenous Protected Areas: phase 1 – Carnarvon Range	\$25K	S van Leeuwen, M Langley, K Quinlan, 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, 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

Partnership name	Project Title	External Funding	DEC Involvement
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 (Golden Eagle Offset)	Ecology and management of bilby in the Pilbara	\$100K (2012–2021), \$60K (2012–2017)	K Morris, S van Leeuwen, 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
International Centre for Radio Astronomy Research, The University of Western Australia, Curtin University	Imaging and CCD photometry of transient objects	Nil	A Verveer
Lowell Observatory, USA University of Maryland, USA	Imaging and spectrophotometry of comets	Nil	A Verveer
Main Roads Western Australia	Ecology and management of northern quoll in the Pilbara	\$25K	K Morris, A Cook, D Pearson
MicroLensing Network for the Detection of Small Terrestrial EcoPlanets	Monitoring gravitational microlenses	Nil	A Verveer
Millennium Seedbank Project	Seed collection, storage and biology	\$128K p.a. to 2011 \$8K in 2012–2013	A Cochrane, D Coates
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 Centre for Phytophthora Science and Management	Molecular investigation of <i>Phytophthora</i> hybrids	\$5K p.a. (2009–2011) Nil 2012–2013	M Stukely
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

Partnership name	Project Title	External Funding	DEC Involvement
Murdoch University	Taxonomic studies of Western Australian marine plants	\$40K p.a. 2011–2013	J Huisman
Murdoch University	Epidemiology of marri canker	Nil	B Shearer
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, A Cartraud, 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 Pennifold
North Australian Marine Research Alliance	Assessing spatial and demographic structure of anthropogenic mortality on Australasian marine turtles	\$300K 2012–2014	S Whiting
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 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	Seed collection zones for the Pilbara	\$100K 2010–2012	M Byrne, S van Leeuwen, D Coates
Rio Tinto	Identification Botanist position at the Western Australian Herbarium	\$114K (to December 2014)	K Thiele
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

Partnership name	Project Title	External Funding	DEC Involvement
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
Scitech Planetarium, The University of Western Australia, Science Teachers Association of Western Australia	Astronomy education	Nil	A Verveer
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, Caring for Our Country, DEC South Coast Region	Increasing native habitat through protection of EPBC species and ecological communities (dibbler recovery)	\$30K (2011–2013)	T Friend
South Coast Natural Resource Management	Great Western Woodland vegetation map reconciliation project	\$100K	S van Leeuwen, R Coppen, C Bishop, B Bayliss
Space Telescope Science Institute, USA; South African Astronomical Observatory; Institut d'Astrophysique, France; U Potsdam, Germany; University of St Andrews, Scotland; University of Tasmania	PLANET: Monitoring gravitational microlenses	Nil	A Verveer
State NRM	Fast track critically endangered flora recovery	\$1.6M 2013–2015	D Coates
State NRM	Recovery of the critically endangered woylie	\$250K over 12 months	A Wayne, C Vellios, C Ward, M Maxwell
State NRM	Emergency recovery actions for highest priority threatened flora	\$870K	D Coates
Terrestrial Ecosystem Research Network (TERN)	TERN: ecoinformatics facility and development of ecological databases and portals	Nil	P Gioia
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 Coppen, R Meissner
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 Langlely, N Gibson
The University of Western Australia	Mode of action of phosphonate in native hosts to <i>Phytophthora cinnamomi</i>	Nil	B Shearer

Partnership name	Project Title	External Funding	DEC Involvement
The University of Western Australia	Variable star observations	Nil	A Verveer
The University of Western Australia	Genetic diversity of corals in the Montebello and Barrow Islands MPAs	Nil	S Field
University of Adelaide	Mundulla Yellows disease of eucalypts	Nil	M Stukely
University of Adelaide	Wetland monitoring program: rotifer and cladoceran identifications	Nil. Ongoing informal collaboration on aquatic microinvertebrate systematics for DEC aquatic science projects.	A Pinder, D Cale
University of California, Berkeley and Lawrence Hall of Science	Hands-On Universe: internet telescope	\$1K	A Verveer
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 Nebraska, Omaha USA	Fire ecology of hummock grasslands	Nil	B Ward
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
Walpole – Nornalup National Parks Association; Walpole Wilderness Eco-Cruises	The impact of wildfire on invertebrate communities in old growth forests	Nuyts Wilderness Community Trust funds annual collection curation	P Van Heurck, T Middleton
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, A Burbidge, N McKenzie
Western Australian Museum	NatureMap: data sharing and joint custodianship	Nil	P Gioia
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 PROJECTS BY DEC, NRM, IBRA/IMCRA REGIONS

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
BIODIVERSITY AND CLIMATE CHANGE UNIT: COLIN YATES				
Midwest	Geraldton Sandplains	Northern Agricultural	Climate change risks for biodiversity and ecosystem function in species-rich shrublands	44
Goldfields, Warren, Wheatbelt	Coolgardie, Mallee, Avon Wheatbelt, Warren	Wheatbelt, Rangelands, South Coast	Climate-resilient vegetation of multi-use landscapes: exploiting genetic variability in widespread species	45
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>	48
South Coast, Warren, Wheatbelt	Esperance Plains, Mallee, Jarrah Forest, Avon Wheatbelt, Warren	Wheatbelt, South Coast, South West	Protecting the safe havens: will granite outcrop environments serve as refuges for flora threatened by climate change?	46
Warren	Warren	South West	Restoring natural riparian vegetation systems along the Warren and Donnelly Rivers	43
Midwest, South Coast, Swan, Warren, Wheatbelt	Esperance Plains, Mallee, Geraldton Sandplains, Jarrah Forest, Swan Coastal Plain, Avon Wheatbelt, Warren	Wheatbelt, Northern Agricultural, South Coast, South West, Swan	Temperature thresholds for recruitment in south-west Western Australian flora	49
BIOGEOGRAPHY PROGRAM: STEPHEN VAN LEEUWEN				
South Coast	Esperance Plains, Mallee	South Coast	Biological survey of the Ravensthorpe Range	55
All	All	All	Development of ethically acceptable techniques for invertebrate wet-pit trapping	54
Goldfields, Midwest	Coolgardie, Murchison, Gascoyne, Avon Wheatbelt, Yalgoo	Northern Agricultural, Rangelands	Floristic surveys of the banded iron formation and greenstone ranges of the Yilgarn	56
Kimberley	Dampierland, Northern Kimberley, Victoria Bonaparte	Rangelands	Kimberley islands biological survey	56
All	All	All	Oligochaete taxonomy	58
Pilbara	Pilbara	Rangelands	Pilbara regional biological survey	57

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
Goldfields, South Coast, Warren, Wheatbelt	Esperance Plains, Murchison, Mallee, Jarrah Forest, Avon Wheatbelt	Wheatbelt, South Coast, Rangelands	South-Western Australia Transitional Transect (SWATT)	50
All	All	All	Western Australian flora surveys	51
All	All	All	Western Australian terrestrial fauna surveys	52
All	All	All	Western Australian wetland fauna surveys	53
FAUNA CONSERVATION PROGRAM: KEITH MORRIS				
Pilbara	Pilbara	Rangelands	Conservation and management of the bilby (<i>Macrotis lagotis</i>) in the Pilbara	62
South Coast, Warren	Esperance Plains, Jarrah Forest, Warren	South Coast, South West	Conservation of south coast threatened birds	66
Goldfields, Swan	Coolgardie, Swan Coastal Plain	Rangelands, Swan	Conservation of the graceful sun-moth	68
Pilbara	Pilbara	Rangelands	Decision support system for prioritising and implementing biosecurity on Western Australia's islands	61
Midwest, Pilbara, South Coast	Carnarvon, Murchison, Gascoyne, Gibson Desert	Rangelands	Development of effective broad-scale aerial baiting strategies for the control of feral cats	74
Midwest	Swan Coastal Plain	Northern Agricultural	Ecology and conservation of threatened pythons in Western Australia	76
Pilbara	Pilbara	Rangelands	Ecology and management of the northern quoll in the Pilbara	67
Wheatbelt	Mallee	Wheatbelt	Factors affecting fauna recovery in the Wheatbelt: Lake Magenta and Dunn Rock Nature Reserves	71
Pilbara, Swan	Jarrah Forest, Pilbara, Swan Coastal Plain	Rangelands, Swan	Genetic approaches for evaluating the contribution of the reserve system to fauna conservation	64
Kimberley, Pilbara	Dampierland, Northern Kimberley, Pilbara, Central Kimberley	Rangelands	Genetic assessment for conservation of rare and threatened fauna	63
South Coast	Jarrah Forest	South Coast	Gilbert's potoroo (<i>Potorous gilbertii</i>) recovery plan	75
Warren	Jarrah Forest	South West	Identifying the cause(s) of the recent declines of woylies in south-west Western Australia	70
Kimberley	Northern Kimberley, Ord Victoria Plain, Central Kimberley, Victoria Bonaparte	Rangelands	Impact of cane toads on biodiversity in the Kimberley	74
			Improving the use of remote cameras as a survey and monitoring tool	60

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
Goldfields	Gascoyne	Rangelands	Rangelands restoration: reintroduction of native mammals to Lorna Glen (Matuwa)	65
Wheatbelt	Avon Wheatbelt	Wheatbelt, South West	Sustained fauna recovery in a fragmented landscape (Dryandra Woodland and Tutanning Nature Reserve)	72
Midwest	Avon Wheatbelt, Yalgoo	Northern Agricultural, Rangelands	Sustained introduced predator control in the rangelands	69
South West, Swan	Jarra Forest	Wheatbelt, South West, Swan	The importance of fox, cat and native predator interactions to sustained fauna recovery in the northern jarrah forest: is there a mesopredator release effect?	73

FLORA CONSERVATION AND HERBARIUM PROGRAM: DAVID COATES

South Coast, South West	Esperance Plains, Jarrah Forest, Swan Coastal Plain	Wheatbelt, South Coast, South West, Swan	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	98
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	91
All	All	All	Australian wattle identification	108
All	All	All	Biosystematics of fungi for conservation and restoration of Western Australia's biota	79
All	All	All	Conservation status and systematics of Western Australian <i>Acacia</i>	101
All	All	All	Development of interactive identification platforms and content	100
Midwest, South Coast, South West, Swan, Warren, Wheatbelt	Esperance Plains, Jarrah Forest, Swan Coastal Plain, Avon Wheatbelt, Warren	Wheatbelt, South Coast, South West, Swan	Ecophysiology of rare flora restricted to shallow-soil communities	82
South Coast	Esperance Plains, Warren	South Coast	Effects of pre-treatments, microhabitats and on-site management in the translocation success of threatened plant species: an ecophysiological approach	81
All	All	All	FloraBase and biodiversity informatics at the Western Australian Herbarium	88
Wheatbelt	Swan Coastal Plain, Avon Wheatbelt	Wheatbelt, Northern Agricultural, South Coast, Swan	Genetic and ecological viability of plant populations in remnant vegetation	102
Goldfields, Midwest, South	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal	Wheatbelt, Northern	Genetics and biosystematics for the conservation, circumscription and	108

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
Coast, Swan, Wheatbelt	Plain, Mallee, Coolgardie, Murchison, Yalgoo, Esperance Plains	Agricultural, South Coast, South West, Swan	management of the Western Australian flora	
All	All	All	Herbarium collections management	86
			Interactive key and taxonomic studies of Myrtaceae tribe Chamelaucieae	78
Midwest, South Coast, South West, Swan, Warren, Wheatbelt	Esperance Plains, Mallee, Jarrah Forest, Swan Coastal Plain, Avon Wheatbelt	Wheatbelt, Northern Agricultural, Rangelands, South Coast, South West, Swan	Mating system variation, genetic diversity and viability of small fragmented populations of threatened flora, and other key plants of conservation importance	104
Kimberley, Pilbara	Gibson Desert, Great Sandy Desert, Carnarvon, Little Sandy Desert, Central Kimberley, Victoria Bonaparte, Central Ranges, Dampierland, Northern Kimberley, Ord Victoria Plain, Gascoyne	Northern Agricultural, Rangelands	Resolving the systematics and taxonomy of <i>Tephrosia</i> in Western Australia	93
All	All	All	Seed biology, seedbank dynamics and collection and storage of seed of rare and threatened Western Australian taxa	107
All	All	All	Strategic taxonomic studies in families including Amaranthaceae and Fabaceae (<i>Ptilotus</i> , <i>Gomphrena</i> , <i>Swainsona</i>) and other plant groups	80
South Coast, South West, Swan, Warren, Wheatbelt	Esperance Plains, Geraldton Sandplains, Jarrah Forest, Swan Coastal Plain, Avon Wheatbelt, Warren	Northern Agricultural, South Coast, South West, Swan	Strategic taxonomic studies in families including Epacridaceae, Rafflesiaceae, Rhamnaceae and Dilleniaceae	90
Midwest, South Coast, South West, Swan, Warren, Wheatbelt	Esperance Plains, Geraldton Sandplains, Jarrah Forest, Swan Coastal Plain, Avon Wheatbelt, Warren	Wheatbelt, South Coast, South West, Swan	Susceptibility of rare and endangered flora to <i>Phytophthora</i>	106
All	All	All	Systematics of the triggerplant genus <i>Stylidium</i>	95
All	All	All	Taxonomic resolution and description of new plant species, particularly Priority Flora from those areas subject to mining in Western Australia	100
Kimberley, Pilbara, South Coast, South West, Swan, Warren	Geraldton Sandplains, Swan Coastal Plain, Jarrah Forest, Central Kimberley, Victoria Bonaparte, Warren, Dampierland, Northern Kimberley, Esperance Plains, Gascoyne	Northern Agricultural, Rangelands, South Coast, South West, Swan	Taxonomic review and floristic studies of the benthic marine algae of north-western Western Australian and floristic surveys of Western Australian marine benthic algae	96
All	All	All	Taxonomic studies in selected families, including Asteraceae, Celastraceae, Malvaceae, Proteaceae	92
Midwest, South	Coolgardie, Esperance Plains,	Wheatbelt,	Taxonomic studies on native and	90

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
Coast, Swan, Wheatbelt	Mallee, Geraldton Sandplains, Swan Coastal Plain, Avon Wheatbelt	Northern Agricultural, Rangelands, South Coast, South West, Swan	naturalised plants of Western Australia arising from biological survey	
All	All	All	Taxonomy of selected families including legumes, grasses and lilies	94
All	Esperance Plains, Mallee, Geraldton Sandplains, Jarrah Forest, Swan Coastal Plain, Avon Wheatbelt, Warren	All	Taxonomy of undescribed taxa in the Ericaceae subfamily Styphelioideae, with an emphasis on those of conservation concern	89
All	All	All	The Western Australian Herbarium's specimen database	86
All	All	All	The Western Australian Plant Census and Australian Plant Census	85
Kimberley, Midwest, Pilbara, South Coast, South West, Swan, Warren	Geraldton Sandplains, Swan Coastal Plain, Jarrah Forest, Central Kimberley, Victoria Bonaparte, Warren, Dampierland, Northern Kimberley, Esperance Plains	Northern Agricultural, Rangelands, South Coast, South West, Swan	The Western Australian marine benthic algae online and an interactive key to the genera of Australian marine benthic algae	97
Goldfields, Midwest, South Coast, South West, Swan, Wheatbelt	Esperance Plains, Jarrah Forest, Avon Wheatbelt	Wheatbelt, Northern Agricultural, Rangelands, South Coast, South West, Swan	The population ecology of critically endangered flora	105
Midwest, South Coast, South West, Wheatbelt	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Coolgardie, Warren, Esperance Plains	Wheatbelt, Northern Agricultural, South Coast, South West, Swan	Translocation of critically endangered plants	103
Goldfields, Midwest, Pilbara	Pilbara, Tanami, Central Ranges, Gascoyne, Gibson Desert, Little Sandy Desert, Great Sandy Desert, Coolgardie, Great Victoria Desert, Murchison, Yalgoo, Nullarbor	Rangelands	Understanding mulga	80
Midwest, South Coast, South West, Swan, Warren, Wheatbelt	Esperance Plains, Geraldton Sandplains, Jarrah Forest, Swan Coastal Plain, Avon Wheatbelt, Warren	Wheatbelt, Northern Agricultural, South Coast, South West, Swan	Vegetation Health Service	83
LANDSCAPE CONSERVATION PROGRAM: LACHIE MCCAW				
Warren	Warren	South West	<i>Armillaria</i> spread in karri	135
South West, Swan	Jarrah Forest	South West, Swan	Aspects of dieback behaviour relevant to the formulation of jarrah silviculture guidelines	118
Warren	Jarrah Forest	South West	Burning for biodiversity: Walpole fine-grain	123

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
			mosaic burning trial	
South West, Warren	Jarrah Forest, Warren	South West, Swan	Evaluation of key soil indicators of sustainability in Australian mediterranean forests (Indicators 4.1d, 4.1e)	129
South West, Swan, Warren	Jarrah Forest, Warren	South West, Swan	FORESTCHECK: Integrated site-based monitoring of the effects of timber harvesting and silviculture in the jarrah forest	121
Kimberley	Northern Kimberley	Rangelands	Fire regimes and biodiversity decline in the Kimberley	119
Goldfields, South Coast, Wheatbelt	Coolgardie, Mallee, Avon Wheatbelt, Yalgoo	Wheatbelt, Rangelands	Fire regimes and impacts in transitional woodlands and shrublands	115
South Coast, Wheatbelt	Esperance Plains, Mallee, Avon Wheatbelt	Wheatbelt, South Coast, Rangelands	Fire, fragmentation, weeds and the conservation of plant diversity in Wheatbelt nature reserves	117
Goldfields, Midwest, Pilbara, South Coast, South West, Warren, Wheatbelt	Swan Coastal Plain, Geraldton Sandplains, Coolgardie, Jarrah Forest, Esperance Plains, Murchison, Avon Wheatbelt, Mallee	Wheatbelt, South Coast, Northern Agricultural, Rangelands, South West	Genetic analysis for the development of vegetation services and sustainable environmental management	133
Swan	Jarrah Forest	South West, Swan	Hydrological response to timber harvesting and associated silviculture in the intermediate rainfall zone of the northern jarrah forest	128
South West, Warren	Jarrah Forest	Wheatbelt, South West	Identification of seed collection zones for rehabilitation	120
Swan	Jarrah Forest	Swan	Landscape and fire management interactions and their effects on distribution of invertebrate biodiversity	128
Warren	Warren	South West	Long-term stand dynamics of regrowth karri forest in relation to site productivity and climate	113
Midwest, South Coast, Wheatbelt	Esperance Plains, Geraldton Sandplains, Avon Wheatbelt	Wheatbelt, Northern Agricultural, South Coast	Management of environmental risk in perennial land use systems	124
South West, Swan, Warren	Esperance Plains, Mallee, Jarrah Forest, Swan Coastal Plain, Warren	South Coast, South West, Swan	Management of invertebrate pests in forests of south-west Western Australia	114
South West	Swan Coastal Plain	South West	Management of the Vasse–Wonnerup wetlands	130
Warren	Warren	South Coast, South West	Monitoring post-fire effects from the 2001 Nuyts wildfire	122
South West, Swan, Warren	Jarrah Forest, Warren	South Coast, South West, Swan	Monitoring stream biodiversity (KPI 20 of the Forest Management Plan)	121

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
Kimberley	Northern Kimberley	Rangelands	North Kimberley Landscape Conservation Initiative: monitoring and evaluation	112
Goldfields	Murchison, Gascoyne	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	125
Warren	Jarrah Forest, Warren	South West	Responses of terrestrial vertebrates to timber harvesting in the jarrah forest	111
Midwest, South Coast, South West, Swan, Warren, Wheatbelt	Esperance Plains, Mallee, Geraldton Sandplains, Jarrah Forest, Avon Wheatbelt	Wheatbelt, South Coast, Northern Agricultural, South West	State Salinity Strategy wetland monitoring	131
Warren	Warren	South West	The effect of wildfire on forest fungi	133
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Warren	WA South Coast	South Coast	Spatial and temporal patterns in benthic invertebrate communities of the Walpole and Nornalup Inlets Marine Park	146
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RESEARCH ACTIVITIES

BIODIVERSITY AND CLIMATE CHANGE UNIT

MANAGER: COLIN YATES

Climate is a fundamental influence on where plants and animals flourish, what communities and ecosystems develop in a location and what habitat is available there. Climate affects plants and animals directly by determining the temperature regimes and water availability in an area. Climate indirectly affects plants and animals by impacting on many of the most significant forces they experience, including fire, diseases, invasive species and salinity. Climate change has the potential to significantly impact on Western Australia's natural biological diversity.

Climate research through the Indian Ocean Climate Initiative program has demonstrated that climate conditions in south-west Western Australia have changed significantly during the past 40 years; in particular, the climate is becoming warmer and drier. Climate projections indicate that Western Australia faces ongoing climate changes. Managing the potential impacts of climate change on Western Australia's biodiversity requires sound knowledge of the vulnerability of species and communities to direct and indirect impacts.

The Biodiversity and Climate Change Unit focuses on research to develop an understanding of these impacts, especially the impacts on the potentially 'at risk' species, communities and ecosystems of Western Australia. This understanding provides the basis on which management responses to climate change are formulated and undertaken. The Biodiversity and Climate Change Unit includes research scientists from all Science Division programs. It includes strengths in ecology, modelling, surveys, phytogeography, genetics, and fire science.

Restoring natural riparian vegetation systems along the Warren and Donnelly Rivers

SPP 2013-004

Team members

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

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

- Information was compiled for species selection and suitable sampling designs, including climatic distributions and the availability of wild populations spread throughout climatic zones.
- Initial field trips were undertaken with collaborators to assess the suitability of selected species and to identify potential collection sites.
- Initial leaf collections of potential species were made and DNA extraction was undertaken to evaluate suitability for continued work.
- Three study species were selected: *Astartea leptophylla*, *Callistachys lanceolata* and *Taxandria linearifolia*.
- Six species (including the above three) were selected for further climate modelling.

Management implications

Changing climates requires 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)

- Collection of leaf and seed from 12 populations across three climate zones for each of the three species along the Warren River.
- Analysis of genetic adaptation between populations and climate zones for three species.
- Complete climate modelling for six species.
- Undertake experimental plantings of seed collected from populations across the climate gradient.

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 measurements of climate on the Eneabba sandplain.
- Completed climate manipulation experiments (decreased rainfall and increased temperature) on plant demography across the soil depth gradient.

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.

Future directions (next 12 to 18 months)

- Analyse data from ecohydrology and demographic studies and draft papers for scientific journals.
- Analyse data from climate manipulation experiments and draft papers for scientific journals.

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

SPP 2012-002

Team members

M Byrne, C Yates, B Macdonald, E McLean, S Prober (CSIRO), W Stock (Edith Cowan University) (Edith Cowan University), B Potts (University of Tasmania), R Vaillancourt (University of Tasmania), 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

- The study was undertaken on two species, *Eucalyptus salubris* in Western Australia and *E. tricarpa* in Victoria, with nine populations per species sampled across a climatic gradient, with three populations at each of the climatic extremes, and three populations of intermediate climate. For *E. tricarpa*, ecophysiology was also sampled for the same nine populations from within two existing provenance trials, one located at each end of the climate gradient.
- Ecophysiological traits were measured for both species in the natural populations and in field trials for *E. tricarpa*.
- Genomic data was obtained using DArTseq technology and genome wide scans were undertaken for both species.
- 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.
- The end-user reference group was engaged in discussion of results and implications for end users involved in restoration.

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 and write scientific papers.

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, G Wardell-Johnson (Curtin University), L Mucina (University of Western Australia), K van Niel (University of Western Australia), S Hopper (University of Western Australia), 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

- Completed plant species identifications for 450 vegetation plots across environmental gradients on 15 GOs.
- Began integration of plant species records from the floristic survey of 450 plots with environmental measurements of the 15 GOs in database.
- Completed databasing of local climate and microclimate measurements on five focal GOs across environmental gradients.
- Completed modelling of LiDAR and other multispectral remotely sensed data for 28 GO field sites.
- Completed manuscript on 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.
- Completed genotyping and data analysis for phylogeographic and population genetic studies on two common GO endemic plant species, *Kunzea pulchella* and *Stypandra glauca*.
- Completed manuscript on phylogeographic patterns in *K. pulchella* for submission to *Diversity and Distributions*, and commenced manuscript on the phylogeographic patterns in *S. glauca*.
- Continued databasing Hopper's GO species occurrence records.

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)

- Continue to integrate 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.
- Model the influence of microclimate and soil depth on the composition and phenology of GO herbfields, and on the distribution of *Ornduffia calthifolia*.
- Continue entry of Hopper's GO data and check database.
- Publish journal papers on GO as refugia for *K. pulchella* and *S. glauca*.
- Write journal papers on ecological evidence for granite outcrops as historical and future climate change refugia.

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

- Semi-permanent transects for canker monitoring have been established at 48 sites across the south-west.
- Transects have been surveyed over four years and a general increase has been identified in both incidence and severity.
- Three main causal canker organisms have been identified as a disease complex responsible for increases in infection.
- Basic climatic data for the sites have been gathered.
- One new monotypic genus and species of disease-causing canker fungus (*Luteocirrhus shearii*) have been described and is 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.

Management implications

- Cankers have been shown to be increasing in incidence and severity across the south-west and this may to 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)

- Further assessment of canker impact and climate data collection in November 2013.
- Continue to investigate any correlation between climate data and increased canker impact.

- 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) 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

- Manuscript reviewing the evidence for population variation in seed germination and seedling traits across climate gradients was submitted to *Global Ecology and Biogeography*.
- Two manuscripts are currently in draft, detailing the results of laboratory experiments investigating population variation in tolerance to increased temperature and reduced moisture availability during seed germination in four *Banksia* species.
- A manuscript is in draft, detailing the results of a common-garden experiment investigating the impacts of warming and increased/decreased rainfall relative to ambient temperature on seedling emergence (total and timing of) and growth (biomass allocation, leaf number, leaf production rate and specific leaf area).

Management implications

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

Future directions (next 12 to 18 months)

- Determine the influence of projected climate change on seed and seedling traits in *Banksia* species along an east–west climate gradient in Western Australia.
- Submit draft papers to scientific journals describing the investigations undertaken for *Banksia* species on population variation in seed germination and seedling growth under the influence of climate change.
- Submit a paper to a scientific journal describing temperature thresholds for *Banksia* germination under the influence of a warming climate.
- Analyse data from a glasshouse experiment manipulating ambient climate and prepare a draft manuscript describing the effects of experimental treatments on seedling performance of *Banksia* species.

BIOGEOGRAPHY PROGRAM

PROGRAM LEADER: 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 Environment and Conservation. 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

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 vegetation occurring on deep sand plains across the transect.

Aims

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

Summary of progress and main findings

Five and a half sites have been established on the transect and soil samples for textural and chemical analysis have been collected. Opportunistic sampling of flowering plants has commenced prior to comprehensive floristic sampling in spring.

Management implications

A more detailed understanding of the beta-diversity patterns of the sandplains will allow:

- implications of large-scale development proposals on biodiversity values to be better understood;
- 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.

Future directions (next 12 to 18 months)

Following the establishment of the ten sites on the transect, a comprehensive vegetation survey of 160 quadrats (16 quadrats per site) will be undertaken in the 2013 spring season.

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:

- Surveys of selected areas in national parks as part of DEC's NatureBank program to assist in decisions on future possible developments.
- Surveys of Cane River and Credo Reserves in conjunction with the Department of Sustainability, Environment, Water, Populations and Communities funded Bush Blitz program that gathers information on the National Reserve System.
- Establish a series of AusPlots Rangeland survey sites as a baseline for long-term monitoring in collaboration with the Terrestrial Ecosystems Research Network (TERN).
- Undertake flora survey of the Carnarvon Range Indigenous Protected Area (IPA) in collaboration with the Birriburu Native Title Claimants to aid future management.
- Undertake floristic survey and mapping of the halophyte-dominated communities of the Fortescue Marsh.

Aims

- Undertake floristic survey of Cane River Conservation Park and proposed Credo Station Conservation Park as part of the ABRS-managed Bush Blitz program.
- Undertake targeted floristic survey of proposed NatureBank site in Cape Le Grand National Park.
- Establish 70 AusPlots Rangeland survey sites using the TERN protocol.
- Undertake a floristic survey of the Carnarvon Range to inform management of the recently declared Indigenous Protected Area (IPA).
- Undertake floristic survey and mapping of the halophyte dominated communities of the Fortescue Marsh.

Summary of progress and main findings

- Cane River and Credo surveys completed, reports written and voucher specimens lodged in the WA Herbarium.
- Cape Le Grand survey completed, report written and voucher specimens lodged.
- Established one AusPlot in the first field sampling session in the Coolgardie Bioregion.
- Undertaken two field trips to the Carnarvon Range in contrasting seasons. Have completed identifications of the collections made on the first field trip and selected 600 voucher specimens. Identification of the collections made on the second field trip is continuing.

- Desktop study of available literature and GIS layers completed. Logistics planning and survey design completed.

Management implications

- Data from Cane River and Credo Bush Blitz campaigns will increase the ability of regional conservation managers to understand local biodiversity patterning and its underlying drivers. Regional conservation managers can use the data to assess environmental impacts, prioritise conservation actions, set biodiversity management targets and establish baselines for monitoring. Description of new species discovered during the survey campaigns provides greater knowledge of the flora.
- The Cape Le Grand NatureBank survey identified a new population of a critically endangered plant species that substantially increased the number of plants known in the wild. Populations of a further 21 species of significance were made in the survey area. Data from this survey will inform future management of this area.
- The Carnarvon Range survey has more than doubled the number of known taxa from the area, it has also 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 mapping project will provide documentation of the conservation values of the Marsh and input into ongoing management and environmental approvals processes.
- 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.

Future directions (next 12 to 18 months)

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

Western Australian terrestrial fauna surveys

SPP 2011-021

Team members

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

Context

The Department of Environment and Conservation (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 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 to inform local conservation planning and as baselines for future monitoring.

- Gather and interpret data on the distribution, ecological tolerances and conservation status of terrestrial species and communities.

Summary of progress and main findings

- Carnarvon Range biological survey undertaken in May 2013 targeted mammals, reptiles, birds and selected invertebrates (both terrestrial and wetland), and included plants. Report in progress.
- Assisted South Coast Region with the survey of the Wilderness Area in Fitzgerald River National Park, which targeted mammals, reptiles and birds. This information will provide context for management decisions around the proposed walk trails at each end of the park. Report in progress.

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 managers to understand local biodiversity patterning and its underlying drivers, and allow them to use 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 bioregionalisation analyses, analysis 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)

Two surveys in the Great Victoria Desert region will provide biological information for two areas where such information is lacking (DSEWPaC initiative). Further survey planned for the Carnarvon Range, as well as establishing monitoring sites. Other similar surveys will be ongoing and undertaken as required.

Western Australian wetland fauna surveys

SPP 2011-018

Team members

A Pinder, K Quinlan, RJ Shiels (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 higher resolution at smaller 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 will run on an 'as-needed' basis.

Aims

- Provide understanding of medium-scale (catchment/wetland system) aquatic biodiversity patterning 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

- Sampled and identified aquatic invertebrates at 25 wetlands along the Cervantes to Coolimba coastline in 2011.
- Data from the Cervantes to Coolimba Springs survey written up as a report to the Western Australian Department of Water.
- Analyses of all Cervantes to Coolimba sites almost complete and a paper is being prepared.

- Undertook two rounds of sampling wetlands in the Carnarvon Ranges (Birriluburu) as part of a broader collaboration to survey biodiversity in these ranges with Central Desert Native Title Services and the Martu Aboriginal community from Wiluna.

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. Most of the region's wetlands are groundwater dependant to some extent and conservation of the fauna will require sustainable groundwater management to maintain hydrological regimes, including the permanent freshwater springs. The springs provide a permanent over-summer refuge (and recolonisation source) for a significant proportion of the region's aquatic invertebrate fauna. The seasonally inundated salt lakes support most of the known populations of the endemic brine shrimp *Parartemia extracta* so this needs to be considered when assessing future applications to expand gypsum mining from the single lake in Beekeepers Nature Reserve.

Future directions (next 12 to 18 months)

- Complete a paper on the aquatic invertebrates of the Cervantes to Coolimba region.
- Publish a report or paper on the aquatic invertebrate diversity and conservation significance of the Three Springs mound springs.

Development of ethically acceptable techniques for invertebrate wet-pit trapping

SPP 2010-005

Team members

M Cowan, N Guthrie, T Oldfield (Consultant Vet), D Harris (WA ChemCentre), K Ho (WA ChemCentre), 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 and biogeographic research 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 surveying 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

- Preliminary analysis of data from two field examinations of alternative oil/ethanol chemistries showed no significant bias in either invertebrate captures or vertebrate by-catch captures between the original glycol-based solutions and the new oil/ethanol solutions.
- The interaction of oil layers over ethanol as an alternative to pure glycol continues to pose issues in that a boundary layer forms between the two chemicals that inhibits animals with high surface to volume ratios transferring from the oil to the ethanol preservative.

- Trials have been conducted to examine the efficacy of molecular and morphological preservation of invertebrates using a combination of propylene glycol and ethanol. Evaporation of ethanol is reduced through mixing with propylene glycol and the ratio of these chemicals can be set to maintain a low density.
- Initial results show good preservation of specimens for molecular analysis.

Management implications

Identification of an acceptable chemical solution will enable continued use of invertebrate wet-pit sampling, which is essential for a number of broad-scale biodiversity monitoring programs underway within DEC, as well as for environmental impact assessment and conservation planning through regional- and local-scale biological surveys.

Future directions (next 12 to 18 months)

- Verify that both vertebrate and invertebrate material is suitable for morphological and molecular studies after immersion in preserving solution.
- Optimise the ratio of propylene glycol with ethanol to maximise preservation while minimising evaporation of ethanol.
- Develop trap design parameters through laboratory trials to minimise ethanol evaporation.
- Field trial chemistry and trap design.

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 biological 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 the botanical and invertebrate biodiversity values of the Ravensthorpe Range.

Summary of progress and main findings

- Paper on Ravensthorpe Range vegetation communities published in *Conservation Science Western Australia*.
- Paper on correlation between floristic communities and vegetation mapping is in preparation.

Management implications

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

Future directions (next 12 to 18 months)

Finalise publication of paper on the correlation between floristic communities and vegetation mapping.

Floristic surveys of the banded iron formation and greenstone ranges of the Yilgarn

SPP 2007-005

Team members

N Gibson, R Meissner, R Coppen

Context

Assessment of the conservation significance of the flora and vegetation of the banded iron formation (BIF) and greenstone ranges of the Yilgarn is required, as they are little studied and under increasing pressure from the rapidly expanding mining interests south of the Pilbara. These land systems and geological units are highly prospective for mineral exploration and resource development but are inadequately documented in respect to botanical diversity, and are poorly reserved.

Aims

Undertake a detailed floristic survey of the banded iron formation and greenstone ranges of the Yilgarn to identify gaps in the present reserve network and to determine areas of high biological significance.

Summary of progress and main findings

Last six papers on floristic patterns of greenstone ranges published in *Conservation Science Western Australia*.

Management implications

BIF and greenstone botanical surveys provide a regional context for the assessment of the impacts of proposed developments on the conservation values of flora and vegetation on these ranges.

Future directions (next 12 to 18 months)

This project has been completed.

Kimberley islands biological survey

SPP 2007-001

Team members

L Gibson, M Lyons, R Palmer, D Pearson, G Keighery, M Cowan, N McKenzie, F Koehler, W Caton, T Handasyde, V Kessner

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 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, nonrenewable resource extraction and infrastructure development.

Summary of progress and main findings

- Publication of eight scientific papers (background/logistics, non-volant mammals, land snails, bats, birds, frogs, Traditional Owner perspective and reptiles) and one further paper in press (synthesis) in a dedicated edition of the Records of the Western Australian Museum (WAM), Supplement 81 (available online via WAM website).
- A further paper (plants) is in advanced draft form.
- Popular article published in *LANDSCOPE* (Winter 2013) describing biodiversity patterns on Kimberley islands.
- Workshop with the DEC Kimberley Region regarding the significance of the results of the survey.
- Presentations at various forums regarding Kimberley island biodiversity.

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)

- Complete and submit the plant paper to the *Records of the Western Australian Museum Supplement*.
- 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, A Burbidge, S van Leeuwen, M Lyons, A Pinder, M Langley, J Rolfe, N Gibson, L Gibson, A Markey, S Halse, P Doherty, M Harvey, B Heterick, D Blinn, N Gunawardene, E Volschenk, A Baynes, R Johnstone, T Weir

Context

The Pilbara is an economically important region in Western Australia, with major and expanding mineral extraction industries and pastoral industries. Effective biodiversity conservation is needed to minimise the adverse impacts of these activities and other threatening processes, such as altered fire regimes. 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.
- Identify gradients in community composition and the environmental factors related to these gradients.

Summary of progress and main findings

- The reptile and frog paper is now published online, as is the paper on the original bird fauna.
- The stygofauna paper has been sent for review.
- The wetland aquatic flora and riparian flora papers are 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 preparation in conjunction with CSIRO.
- The survey team are providing data, publications, presentations and advice on the survey's findings to a range of regional stakeholders, including the pastoral and mining industry, DEC regions, EPA/OEPA, Commonwealth agencies (DSEWPaC) 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 region as a regional context for environmental protection. Voucher collections that have been curated, identified and lodged in state natural history collections 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.

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

- Organised the 12th International Symposium on Aquatic Oligochaeta in Fremantle, Western Australia, September 2012.

- Organised a national workshop on identifying marine and freshwater oligochaetes in September 2012.
- Collected aquatic oligochaetes with international colleagues in the Margaret River and Northcliffe areas in September 2012. At least 14 genetic lineages of phreodrilids were found.
- Partially processed a collection of aquatic oligochaetes from Campbell Island in the subantarctic on behalf of EOS Ecology in New Zealand.

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.
- Edit proceedings of the 12th International Symposium on Aquatic Oligochaeta.
- Collect and describe locally endemic oligochaetes from Wheatbelt and Goldfields granite outcrops.
- Update data on Australian Faunal Directory.

FAUNA CONSERVATION PROGRAM

PROGRAM LEADER: KEITH MORRIS

Applied research undertaken by the Fauna Conservation 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.

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

SPP 2013-005

Team members

N Thomas, M Cowan

Context

The use of remote cameras 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 DEC use of remote cameras 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 more 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 methods for estimating the presence and relative abundances of native and introduced mammal species in the south-west of Western Australia.
- Determine the amount of deployment time required to accurately determine mammal species richness within Dryandra Woodland.
- Improve and standardise use of remote cameras within DEC.
- Investigate the effectiveness of baited (active) and unbaited (passive) camera sets to inventory targeted species.
- Compare the detection rates of different makes and models of camera traps.
- Investigate and assess the most appropriate methods of image analysis and data storage.
- Establish the minimum spatial distance required between camera traps to ensure independence of detections.

Summary of progress and main findings

- An initial trial of baited (active) versus unbaited (passive) camera traps was completed. This indicated that baited camera traps are effective in attracting certain species but these species subsequently dominate the cameras and actively exclude other species, resulting in biased data.
- A preliminary comparison of a select number of makes and model of camera traps showed that Reconyx cameras were the most suitable for research and operational purposes.

- Camera traps at Dryandra Woodland detected a number of threatened species that were either not monitored at all, or were unreliably detected, through conventional Western Shield monitoring programs.
- Several different data capture methods were assessed, including commercial image processing software, manual data entry, using an open source database, and an application designed specifically for camera-trap data capture. The most appropriate system for DEC use has been determined.

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.

Future directions (next 12 to 18 months)

- 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 how sensitive camera-trap data are to detecting changes in relative abundance and occupancy of targeted species over time.

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 prioritize 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 islands along the Pilbara coast.

Aims

- Develop a single comprehensive database on Pilbara island characteristics, fauna, flora, 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

- Scoping workshop to identify suitable islands, data sources, and model parameters occurred in Queensland in October 2012.

- First workshop with Pilbara island managers to review the approach and obtain preliminary parameters for model formulation and data occurred in February 2013.
- Formal data requests made to several private companies operating on or near Pilbara islands.
- Obtained data resources held by DEC libraries and Karratha office.
- Island database is estimated to be 80% 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)

- Identify data gaps and organise field trips or expert elicitation procedures required to fill gaps.
- Formulate model and sub-model components.
- Organise additional workshops with island managers to review model parameters and formulation.
- Test the decision support tool and train managers in application of the model.

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

SPP 2012-035

Team members

M Dziminski, K Morris, F Carpenter

Context

The greater bilby (*Macrotis lagotis*) is listed as Vulnerable under the *Commonwealth's Environment Protection and Biodiversity Conservation Act 1999*. Increased threatening processes, including pressure from mining activities across the Pilbara, means that greater understanding of the distribution, abundance and ecology of the bilby is important 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 presence/absence of the bilby in the Pilbara and to establish appropriate survey and monitoring techniques, including genetic approaches, for the greater bilby.

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

- Central database established through the NatureMap website to capture records for bilby (and other EPBC-listed fauna) in the Pilbara.
- Collection of recent and historic records for the Pilbara region from review of published and grey literature and existing databases near completion.
- Contact established with relevant experts and departmental staff to gather additional records. Liaison with mining companies in the Great Sandy Desert established via the Rangelands NRM.

- Trials to assess transect monitoring methods commenced in known bilby locations.
- Scat collection and DNA extraction methods trialled using bilby faecal samples.
- Three collaborations initiated with industry and research institute for future survey and monitoring options.

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)

- Manage and maintain an accurate and up-to-date database of bilby records for the state. Continue fieldwork to establish the presence/absence of bilbies across the Pilbara Bioregion.
- Develop efficient and effective survey and monitoring methods for the bilby.
- Identify and establish long-term monitoring sites in collaboration with landholders and mining companies to obtain ongoing records and understanding of bilby occurrence and distribution.

Genetic assessment for conservation of rare and threatened fauna

SPP 2012-034

Team members

K Ottewell, M Byrne, K Morris, D Coates, J Dunlop, R How (Western Australian Museum)

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 informs us of the 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.

Summary of progress and main findings

- Completed genetic and statistical analysis of golden bandicoot translocations. Genetic diversity has been successfully maintained in translocated populations of golden bandicoots at Lorna Glen, Hermite and Doole Islands. Population viability analysis showed that if population sizes are kept lower than ~1000 animals, genetic diversity will be eroded over time and augmentation will be required.
- The majority of tissue samples of *I. obesulus*, *I. auratus*, *I. macrourus* and their subspecies have been sourced for taxonomic analysis.
- Mitochondrial and nuclear sequencing markers have been trialled for phylogenetic informativeness.

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. The fenced enclosure at Lorna Glen currently supports ~300 animals, therefore augmentation of the population will be required to maintain genetic diversity over time. Expansion of the enclosure would enable a larger population to be maintained and will benefit the long-term viability of the translocated bandicoot population at Lorna Glen.
- Resolution of taxonomic boundaries between *I. obesulus* and *I. auratus* will enable revision of current threatened species status.

Future directions (next 12 to 18 months)

- Finalise submission of manuscript on genetic analysis of translocated golden bandicoots.
- Finalise collection of *I. auratus* and *I. obesulus* tissue samples and complete DNA extractions.
- Complete sequencing of mitochondrial and nuclear markers for taxonomic analysis of *Isoodon* spp.
- Prepare manuscript on taxonomy and phylogeny of *I. auratus*, *I. obesulus* and *I. macrourus*.

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, P Doughty (Western Australian Museum), B Chambers (University of Western Australia), L Valentine (Murdoch University), A Hillman (Murdoch University), R How (Western Australian Museum)

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

- Sourced and collated quenda tissue samples and associated data from various sources within DEC, University of Western Australia and Murdoch University.
- DNA extraction and genotyping of quenda samples commenced.
- Pilbara mammal species have been selected for study and tissue samples have been sourced for several 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.
- Develop mitochondrial and nuclear DNA sequence markers variable in Pilbara target species and complete sequence analysis.
- Develop niche-based species distribution models for Pilbara mammal species and correlate with genetic data.

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

SPP 2012-024

Team members

C Sims, K Morris, T Chapman, N Burrows, J Dunlop

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. An important component of this is the reintroduction of 11 arid zone mammal species following the successful control of feral cats and foxes

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. The original vision for the Western Shield fauna recovery program was to expand introduced predator control and translocations beyond the south-west once an operational feral cat control program had been developed, and this was also recommended by the independent review of Western Shield in 2003.

Potentially, Lorna Glen could support one of the most diverse mammal assemblages in arid Australia, 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.

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Aims

- Reintroduce 11 native mammal species to Lorna Glen by 2020.
- Re-establish ecosystem processes and improve the condition of a rangeland conservation reserve.
- Improve the conservation status of some threatened species.
- 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

- Additional Mala and Shark Bay mice were translocated into the enclosure.
- 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.
- Active release of 49 golden bandicoots outside of the enclosure failed primarily due to feral predators. Subsequently, a review of the aerial baiting program revealed a failure of delivery technique and higher than expected predator numbers. Bait delivery has been corrected for 2013, but environmental conditions will impact future baiting results. However, passive 'leakage' from the enclosure and survival to maturity of some bandicoots continues to occur.
- 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.

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 DEC'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)

- Develop a 10-year fauna translocation plan, and identify resourcing.
- Ongoing monitoring of bilbies and possums outside the enclosure, and of bandicoots, boodies, mala and Shark Bay mice inside the enclosure.
- Proposed expansion of the enclosure over the next several years, to accommodate larger and genetically sustainable populations of species sensitive to cat predation.
- Develop strategies for releases of boodies and bandicoots outside the enclosure in the presence of low densities of feral cats.
- Continue monitoring the relative abundance of feral cat, fox and dingo populations on the wider property.
- 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

A 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 have been refined through use of audio recordings.
- Methods to improve the success of scrub-bird translocations have been evaluated and improvements identified, including the importance of evaluating potential territory quality.
- In collaboration with South Coast Region, continued to develop a captive management program for western ground parrots; currently exploring options and protocols for captive breeding.

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.
- 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).
- Using previously gathered data on genetic relatedness of captive ground parrots, develop protocols for establishment of a captive breeding program for western ground parrots.
- Assist with developing protocols for moving the captive ground parrots to a new facility outside the department, and for future management of these birds.

Ecology and management of the northern quoll in the Pilbara

SPP 2011-005

Team members

A Cook, K Morris

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 demographics 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 sites identified by BHP Billiton continues and will be completed at the end of 2013.
- Consultation with landholders to gather anecdotal and historical records of northern quoll distribution was commenced in late 2011 and continues.
- Distributional study using motion sensor cameras was commenced in late 2011 and continues with more than 40 sites surveyed. This includes habitat assessment.
- Seven sites have been identified through camera surveys and are considered to have suitable quoll populations for inclusion in the long-term monitoring program.
- Preliminary trapping has been conducted at two of these sites. Trapping at other sites will commence in Aug/Sept 2013.

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 that maybe detected at mining sites.

Future directions (next 12 to 18 months)

- Motion sensor cameras will be deployed at more sites (up to 60 more) to record presence/absence data and patterns of distribution across the Pilbara region.
- Consultation with landholders to gather anecdotal and historical records of northern quoll distribution will continue.
- Long-term regional monitoring commenced in early 2013 and will be conducted twice annually. Monitoring of disturbed areas will conclude in late 2013.

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 gratiose*) 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 management strategies to enable effective conservation of rare fauna.

Summary of progress and main findings

- Completed surveys and monitoring of graceful sun-moth populations in Feb–March.
- Conservation status of graceful sun-moth has changed from Vulnerable to Priority 4.

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 Not threatened (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.

Sustained introduced predator control in the rangelands

SPP 2007-004

Team members

D Algar

Context

The project will provide for the successful reconstruction and conservation of biodiversity as part of the future expansion of the Western Shield program into this region. The program builds on the successful research programs and operational trials conducted in the interior of the arid zone at the Gibson Desert Nature Reserve and more recently at Lorna Glen. The research is focussed on Australian Wildlife Conservancy's Mt Gibson Sanctuary and at the nearby DEC-acquired pastoral leases of Karara–Lochada. Feral cat bait and baiting methods (i.e. timing of baiting, baiting intensity and frequency) will be used to assess an integrated introduced predator (feral cat, fox and wild dog) control strategy.

Aims

Develop operational-scale introduced predator control techniques for the semi-arid bioregions in the southern rangelands.

Summary of progress and main findings

- Two papers on predator control and mark–recapture analysis submitted.
- Two papers on genetic analysis of feral animals published or in press.
- An overarching manuscript that ties the various mesopredator programs together is also currently being drafted by the various collaborators.

Management implications

Research into the development of baiting strategies to provide sustained and effective integrated control of introduced predators over time will extend operational control of introduced predators and wildlife reintroductions to the rangelands. This project demonstrated that long-term, sustained control of feral cats and foxes can be achieved in the rangelands. Some native species, like mala (*Lagorchestes hirsutus*) and greater stick-nest rats (*Leporillus conditor*), may possibly only survive when introduced predators are completely absent—these species will need offshore and ‘mainland islands’ (i.e. fenced areas) to survive. However, a large number of native species can survive if introduced predator densities are reduced (rather than eliminated).

Future directions (next 12 to 18 months)

This project has been completed.

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 relisted as Endangered at the state and federal level and Critically Endangered by the International Union for Conservation of Nature (IUCN).

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

- Ongoing monitoring indicates that numbers have remained approximately stable at a regional level since 2008, except at Keninup and Warrup where declines have continued.
- Evidence indicates that the woylie declines have been mortality-driven, principally due to the predation (particularly by cats) of individuals thought to 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 250–300 in April 2013.
- Collaborative disease investigations continue, particularly into the key associations with the declines.
- Several papers from this work have been recently published in scientific journals.

Management implications

- The woylie has been nominated as Critically Endangered at the state level and will be considered at the federal level thereafter. An elevation in conservation status may increase the recognition, imperatives and funding prospects for directed conservation and recovery efforts for the species.
- The importance of insurance populations to conserve the remaining genetic diversity increases as the declines continue. Continued loss of genetic diversity due to important woylie

populations remaining small or becoming extinct will compromise the recovery prospects and long-term conservation of the species.

- Population management strategies are needed to direct priorities and deliver greater conservation outcomes for important woylie populations. These need to include the effective management of key threats and genetic variability, and adequate monitoring and evaluation of both woylies and key threats. 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 through making animals more vulnerable to predation. Resolution of the role of disease in the declines will directly inform woylie recovery strategies and management.

Future directions (next 12 to 18 months)

- Finalise publication of results.
- This project has been completed.

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 be examining 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.

- 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

- Scoped the framework for the synthesis report and commenced drafting.
- Provided findings from this study and other mesopredator projects to Western Shield.

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)

Prepare the final report, contribute to the mesopredator synthesis report, and publish results.

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

- Monitoring of woylie populations in Dryandra Woodland and Tutanning Nature Reserve was undertaken. Comparative survival was calculated using the live captures component of the Program MARK analysis package, and no difference in woylie survival between the two sites was observed.
- The predominant predator of woylies in Dryandra Woodland and Tutanning Nature reserve is the feral cat. A mesopredator release of feral cats in fox-baited areas has been quantified. Cat density is higher in fox-baited areas where fox density is lower than in unbaited areas.
- Western Shield monitoring in Tutanning Nature Reserve in 2011 resulted in no captures of woylies. Subsequent intensive trapping at Tutanning Nature Reserve resulted in the capture of two individuals (one male and one female). These (and other) woylies are being incorporated into insurance populations for the species.
- Some predation of woylies by foxes continues to occur due to a very high uptake of baits by non-target species (birds and brushtail possums) and thus baits are not available for fox control. Increasing the intensity of fox baiting to 50 baits per square kilometre did not result in increased woylie survival. It appears there was an increase in cat predation when increased fox control was implemented.
- Although some foxes appear to persist within the two baited areas for more than one baiting event, the fox baits (3 mg Probaits) are still effective in killing the majority of foxes that enter these areas, as evidenced by the collection of numerous fox carcasses and 90–95% of foxes being detected on only one occasion based on DNA analysis.
- 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 Probaitis is essentially effective and needs to be maintained to afford fox control. No differences in the uptake of Probaitis 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.
- Complete this project and close the SPP.

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 DEC 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 DEC'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

- Scoped the framework for a synthesis report incorporating all mesopredator research study sites.
- Contributed information from the northern jarrah forest to the synthesis report.

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 report. 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 DEC 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 field in the east Kimberley.
- Field test conditioned taste aversion (CTA) 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.
- Commenced planning for release of 'teacher' toads at the front of cane toad invasions to reduce the likelihood of native fauna eating adult cane toads.

Management implications

- This project has identified which native species are most at risk from ingestion of 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, particularly on islands.

Future directions (next 12 to 18 months)

- Undertake 'teacher' toad trials in the wet season.
- Publication of studies on the susceptibility of Kimberley snake and goanna species to poisoning from cane toads, and on taste aversion trials.

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

- Preliminary work has been conducted for the cat eradication program on Dirk Hartog Island as part of the Dirk Hartog Island National Park Ecological Restoration Project. This work has focussed mainly on obtaining the necessary permits and approvals to begin construction of the camp-site, erection of the cat barrier fence, and positioning of the monitoring grid across the island. It is anticipated that the baiting program will commence in late autumn/early winter 2014.
- Stage 1 of the management plan for the control of cats and black rats on Christmas Island has been completed and stage 2 implemented. All domestic cats have been desexed, microchipped and registered, and over 450 stray/feral cats have been removed. For the second year in a row there has been nestling success of the red-tailed tropicbird, a result of cat removal from the shoreline colony. If further funding can be obtained stage 3, the eradication of cats from the national park and surrounds, will be initiated.
- The feral cat baiting program on the Fortescue March was effective in 2012 with an estimated 60% reduction in cat abundance following baiting.
- Research into the effectiveness of baiting strategies and monitoring techniques are continuing to be assessed under the temperate climatic conditions of the south-west at Cape Arid National Park.

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 one of the world's rarest marsupials. 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 DEC, South Coast and Warren

Regions, South Coast NRM, Murdoch, Edith Cowan and Adelaide Universities, 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 of Gilbert's potoroos is conducted three times a year. Numbers have remained stable since 2001 when this regime was introduced. Sixteen potoroos were known to be alive in November 2012.
- The translocated population on Bald Island has grown rapidly from the founder number of ten. Between 60–70 potoroos are known to be alive, and about another 50 have been removed since 2008 and translocated to the enclosure at Norman's Beach, Waychincup National Park.
- A further nine animals were transferred from Bald Island to the enclosure at Waychincup National Park. Monitoring of the population in the Waychincup enclosure by trapping, radio-tracking and motion-activated cameras has shown that the potoroos use vegetation types other than that occupied at Two Peoples Bay, and that breeding and recruitment are occurring (five independent young have been recorded so far). At least 28 potoroos are known to be alive in the enclosure.

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 Waychincup 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 Waychincup 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 Waychincup 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.

Ecology and conservation of threatened pythons in Western Australia

SPP 1993-159

Team members

D Pearson

Context

Four of Western Australia's 11 taxa of pythons are listed as threatened or in need of special protection. This project will collate distributional information to assess their conservation status more accurately, as well as conduct ecological studies of three species (south-west carpet python, Pilbara olive python and woma python) to determine the habitat requirements, diet and reproductive ecology of these taxa.

Aims

- Document the ecology, distribution and conservation status of threatened and listed pythons in Western Australia.
- Identify conservation threats to pythons and make recommendations for the management of populations.

Summary of progress and main findings

- Curation of collected specimens (road-kills) continued. Some specimens lodged at the Western Australian Museum.
- Mark–recapture study of carpet pythons on Garden Island has continued with occasional visits during warmer months to measure and mark pythons captured by rangers. A total of three new individuals were processed during the year.
- Continued the population genetics study of Pilbara olive python with Dr Peter Spencer of University. Results suggest that the Pilbara olive python is a different species to the Kimberley form.

Management implications

- Resource developments in the Pilbara will impact on various populations of the threatened Pilbara olive python so the genetic study will clarify taxonomic status and guide management decisions.
- Publication of collected data on habitat preferences, diets and activity patterns of woma and Pilbara olive pythons will assist in developing ways to mitigate the impact of mining operations and aid the location of any remnant populations of womas in the wheatbelt.
- The ongoing mark–recapture study on Garden Island provides long-term monitoring information to assess the impacts of the Defence facilities and activity on Garden island and allows for comparison with other snake populations both in Australia and beyond, particularly given recent reports of world-wide snake population declines.

Future directions (next 12 to 18 months)

This project is complete.

FLORA CONSERVATION AND HERBARIUM PROGRAM

PROGRAM LEADER: 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 Environment and Conservation. 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*, *Verticordia* and miscellaneous new combinations (Myrtaceae: Chamelaucieae) were published.

- A paper on *Hypocalymma* and a popular article are in press, and a paper on *Calytrix* 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 *Cyathostemon*, *Hypocalymma* and *Malleostemon* (Myrtaceae).
- 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 50 species of Australian Inocybaceae species, in readiness for an upcoming monograph.
- Produced and trialled an expanded key to the species, genera and major clades of Inocybaceae currently known from Australia.
- Published journal paper describing five new species and records of species of *Inocybe* from temperate and tropical Australia.

Management implications

The availability of scientifically accurate and comprehensive information about taxa of fungi in Western Australia will encourage and allow DEC 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 monograph of the Australian Inocybaceae for the *Fungi of Australia* series.

Understanding mulga

SPP 2012-026

Team members

B Maslin, J Reid, J Sampson, R Rutishauser (University of Zurich), 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 *A. 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

- Paper on identification of the type specimen of *A. aneura* published in *Nuytsia*.
- Electronic (Lucid) key to identification of mulga prepared.

Management implications

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

Future directions (next 12 to 18 months)

- Update Western Australian Herbarium Reference Herbarium to ensure that all taxa are adequately represented there.
- Present series of workshops to staff and consultants on mulga identification (Oct. 2013)

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

- Short communication on the discovery of a presumed extinct species of *Ptilotus* published.
- Draft papers on undescribed species of *Solanum* and *Swainsona* published.
- Two new species of *Westringia* published.

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*.
- Prepare paper on a new species of *Grevillea* from the Great Victoria Desert.

Effects of pre-treatments, microhabitats and on-site management in the translocation success of threatened plant species: an ecophysiological approach

SPP 2012-004

Team members

P Poot, M Moody, R Dillon, L Monks, D Coates

Context

In order for translocations of threatened flora to contribute to the successful recovery of species it is important to better understand the effects of pre-treatments, microhabitats and on-site management on the health, growth potential and ultimately survival of the transplants. In this project we will make use of ecophysiological techniques (e.g. infrared thermal imaging, chlorophyll fluorescence, gas exchange) and environmental monitoring (e.g. soil moisture, incident radiation, rainfall) to monitor how health and physiological activity of seedlings is associated with seasonal changes in environmental conditions. Translocations will be set up as scientific experiments with a range of experimental 'treatments' that will depend on the specific target species and their habitat.

Aims

Develop a better understanding of the causes of failure and success in rare-flora translocations by employing ecophysiological and environmental monitoring techniques to determine the effects of a range of experimental treatments.

Summary of progress and main findings

- The experimental translocation of the Critically Endangered *Banksia ionthocarpa* ssp. *ionthocarpa* in Kamballup Nature Reserve has been monitored for two years. Survival of seedlings after two years is high at 75%, and several interesting differences between

treatments have emerged. Seedlings in plots that were automatically watered each week during summer showed increased survival and enhanced growth, when compared with seedlings that were manually watered once a month. Of the three different microhabitats in which plots were placed in (bare, removed low heath, removed tall heath), seedlings had higher survival and grew most in the low heath plots.

- The experimental translocation of the Critically Endangered *Acacia awestoniana* in the Stirling Range National Park has been monitored for two years. Survival of seedlings after two years is very high at 81%. Although treatments (watering, microhabitat, seedling age at transplant, soil medium pretreatment) did not show significant differences with respect to survival, there were substantial differences in growth. Plants that were watered weekly (automatic) or monthly (manual) during summer showed enhanced growth when compared to non-watered plants. Also, seedlings that were grown on potting mix prior to translocation tended to grow faster than those grown on sand. Faster growth during summer was associated with higher leaf temperatures, as determined by infrared technology.

Management implications

- Increased understanding of the factors that are most relevant to translocation success will improve the conservation status of *Banksia ionthocarpa* ssp. *ionthocarpa* and *Acacia awestoniana*.
- Increased awareness of best practice translocation methods will enable development of recommendations for translocation success criteria that can be used by departmental staff, community groups and industry.

Future directions (next 12 to 18 months)

- Analyse the data collected for both species translocations and prepare manuscripts for publication in international journals on plant conservation biology.
- Evaluate the outcomes of the two experimental translocations in terms of adapting the department's current translocation practices.

Ecophysiology of rare flora restricted to shallow-soil communities

SPP 2012-003

Team members

P Poot

Context

The south-west Australian Floristic Region is recognised as one of only 34 global biodiversity hotspots: those regions on earth richest in endemic species that are also under threat. Approximately 2000 of a total of 8000 plant species in south-west Australia occur on granite outcrops or other shallow-soil environments. Many of these species are shallow-soil endemics that have a highly scattered and often restricted distribution. Also, worldwide a large number of rare species occur in open, shallow, rocky and drought-prone environments. This suggests that shallow-soil endemics may have special adaptations to their own habitats that prevent them from establishing and being competitive in others. Knowledge of these adaptations will help improve our ability to manage and restore shallow-soil ecosystems and the many rare species they contain.

Aims

- Enhance our knowledge of the key adaptations of species endemic to shallow-soil habitats and enhance our understanding of how these adaptations may restrict them in their distribution.
- Use the generated knowledge for optimising management of ecological communities and species that inhabit shallow-soil habitats.

Summary of progress and main findings

A manuscript on rooting strategies in shallow soil habitats was submitted to *Ecological Modelling*.

Management implications

- Revegetation/replanting of perennial vegetation in shallow-soil communities can only be expected to be successful when there are cracks 'available' to the plants' roots in the underlying rock. This may only be the case after fire or after the death of mature individuals. Also, relatively bare areas with low native vegetation cover are unlikely to be useful for revegetation purposes as they have a low water supply.
- Using glasshouse-grown seedlings with relatively few and often stunted and air pruned roots may be especially problematic for revegetation purposes on shallow soils. A high investment in roots appears essential for first-summer survival and glasshouse-grown seedlings often have much higher shoot-to-root ratios.
- Watering over summer may greatly increase survival of transplanted shallow-soil endemics as individuals that did not reach cracks with sufficient water supply before summer get another chance. However, long-term establishment will be dependent on obtaining a more permanent access to a water supply.

Future directions (next 12 to 18 months)

Project now completed.

Vegetation Health Service

CF 2011-112

Team members

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Context

Accurate knowledge of the *Phytophthora* infestation status of particular land units and sites (and adjacent areas), and of its variation over time, is essential and crucial for effective land management and biodiversity conservation. The Vegetation Health Service (VHS) provides a dedicated, specialist scientific service for the detection and identification of *Phytophthora* species from samples associated with the management of Western Australia's forest and conservation estate, logging and mining activities, private industry and research. The VHS is also a service contributor to the Centre for *Phytophthora* Science and Management (CPSM), based at Murdoch University, and participates with CPSM in collaborative research projects.

Mundulla Yellows (MY) is a lethal disease of eucalypts that appears to be well established in various disturbed sites in Western Australia (and in all other states). Over 70 species of eucalypt, in both remnant and planted stands, are affected. The cause of MY is unknown, but there is evidence that a virus or similar organism(s) is involved. Priority research (now being carried out at the University of Adelaide, with DEC collaboration) includes determining the cause(s) of MY and its mechanisms of spread, and the development of a rapid diagnostic test for the disease.

Aims

- Provide a dedicated service for the detection and identification of *Phytophthora* species from samples associated with the management of the state's forest and conservation estate, logging and mining activities, private industry and research, as well as providing a service that is available to external customers on a fee-for-service basis.
- Maintain the VHS's live *Phytophthora* culture collection and the Western Australian *Phytophthora* database, and continue to make these resources available to researchers and land managers.
- Provide advice to assist departmental personnel, external authorities and the public in dealing with *Phytophthora* dieback and other plant disease problems in parks and reserves, forests and other native ecosystems, plantations and nurseries.
- Facilitate and collaborate in research on *Phytophthora*, both within DEC and externally.

- Monitor MY disease occurrence and spread in Western Australia and conduct trials to investigate mechanisms of spread and conditions contributing to development of MY.

Summary of progress and main findings

- A total of 1883 samples from departmental and external sources were processed for *Phytophthora* testing, and all isolates of *Phytophthora* spp. (other than *P. cinnamomi*) were subcultured for identification to species. Isolates were identified by DNA sequencing (through CPSM) as necessary.
- A paper on the *Phytophthora* hybrids occurring naturally in Australia and South Africa was published in *Fungal Biology*.
- The VHS's live *Phytophthora* culture collection and the Western Australian *Phytophthora* database (commenced in 1982) were maintained, expanded and updated. These are now widely recognised as unique and very valuable scientific resources.
- Advice to assist departmental personnel, external authorities and the public has been provided, and input to management plans and manuals was supplied.
- Newly observed MY-affected sites have been checked. Spread of MY symptoms at any given site does not appear to be rapid, and diseased and apparently healthy trees can grow alongside each other. Affected trees have still not been observed within undisturbed forest or woodland stands.

Management implications

- Accurate testing of samples for *Phytophthora* by the VHS is an essential element of the dieback interpretation process for assessing the dieback status of a site and mapping areas affected by *Phytophthora* dieback. A wide range of management decisions for given areas are based on this information, and efficient resource use by managers is dependent upon its accuracy.
- The availability of DNA sequencing technology through the CPSM means that it is now possible to identify sterile *Phytophthora* isolates that cannot be identified using traditional morphological techniques, and also to differentiate between morphologically similar but genetically distinct taxa that had previously been grouped and treated as single morpho-species.
- Most of the newly described Western Australian *Phytophthora* species as well as the undescribed taxa have been associated with dying native plants, which indicates clearly that they have pathogenic capability in natural ecosystems.
- The existence of *Phytophthora* hybrids associated with dying plants in Western Australian natural ecosystems, in addition to the new taxa, indicates that *Phytophthora* species interactions need to be considered as part of a broader approach to *Phytophthora* management.
- It is recommended that the precautionary principle should now be applied in managing all soil-borne *Phytophthora* taxa in natural ecosystems, regardless of their present known impact on plant health, to minimise the opportunities for all *Phytophthora* to spread to new sites, and possibly to hybridise.
- If it is caused by an infectious pathogenic agent, MY has the potential to cause enormous environmental damage if it progresses unchecked. Both remnant and planted trees of all ages can be affected. Once its cause(s), mechanisms of spread and contributing factors are known, the levels of threat posed to vegetation and other wildlife can be estimated, and management strategies can be developed to control the disease and prevent its spread to new areas. The effects of MY are likely to be exacerbated as a result of climate change.

Future directions (next 12 to 18 months)

- Continue to provide *Phytophthora* testing service, and facilitate identification of new *Phytophthora* species.

- Maintain, expand and update the VHS's live *Phytophthora* culture collection and the Western Australian *Phytophthora* database, and continue to make these resources available to researchers and land managers.
- Further develop draft recommendations for managing *Phytophthora* other than *P. cinnamomi*.
- Continue to provide advice to assist departmental personnel, external authorities and the public in dealing with *Phytophthora* dieback.
- Continue monitoring of existing and new occurrences of MY in Western Australia. Grow new seedlings in the glasshouse for MY transmission trials, and harvest foliar material for testing for molecular markers.

The Western Australian Plant Census and Australian Plant Census

CF 2011-111

Team members

S Carroll, C Parker, T Macfarlane, L Biggs, M Falconer, U Sirisena

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 DEC processes and datasets, including the Declared Rare 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 Australian 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 and to obtain accurate national statistics. 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 and fungi in Western Australia, including both current names and synonyms, and integrate with the national consensus.

Summary of progress and main findings

- 395 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 253 registered Max users on a quarterly basis.
- Major families processed for the APC were Ericaceae, Cyperaceae and Malvaceae.
- An update list consisting of two years of accumulated taxonomic changes was processed.

Management implications

- All DEC 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

S Carroll, L Biggs, E McGough, M Falconer, 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 DEC and the community, through the FloraBase and NatureMap websites. Data from the specimen database is provided to researchers, consultants and community members on request.

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 DEC decision support systems and research.

Summary of progress and main findings

- 9351 records were added to the specimen database, including 917 Priority Flora and 96 Threatened Flora.
- 41 requests for specimen data (species lists and label data) were processed for DEC officers, researchers and the public.
- 36022 specimen records were edited during this period.

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, R Cranfield, L Biggs, R Rees, P Spencer, M Falconer, R Davis, S Coffey, M Hislop

Context

The Western Australian Herbarium's collections provide 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 DEC and the community with the fundamental resource providing knowledge of the diversity, distributions 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 DEC.
- Contribute to, support and service taxonomic research by the world's scientific community.

Summary of progress and main findings

- 9351 specimens were added to the collection, which now stands at 742,929, a 1.3% increase in holdings this period.
- The major plant groups in the collection are as follows:

Taxonomic Group	Number of specimens	Increase since June 2012	
	(June 2013)	Number	%
Myxomycetes	905	90	0.01
Fungi	23519	246	0.035
Lichens	16374	83	0.01
Algae	23360	226	0.035
Liverwort and hornworts	1967	1	0.00
Mosses	6714	37	0.005
Ferns and fern allies	3685	51	0.005
Gymnosperms	2039	15	0.00
Flowering plants	664362	8620	1.2
Total number	742929	9351	1.3

- Loans and exchange: loans outward—1197 specimens; loans inward—1105 specimens; exchange outward—1574; exchange inward—304 specimens.
- Volunteer participation was significant, totalling 8740 hours.
- Tasks managed by curation staff with the assistance of volunteers were as follows: general curation of specimens; mounting and labelling 5,351 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 14554 specimens representing 11599 taxa and also added or replaced 320 specimens. Over 2000 visitors used this resource to identify plant specimens during this period.
- The Herbarium Identification Program provides identifications to a range of clients and specialises in taxa and specimens that clients find challenging. This year over 3000 identifications were provided; our most significant clients included DEC, other government agencies, environmental consultancies, regional herbaria and the public.
- Educational role: provided tours of the herbarium for tertiary institutions, secondary schools, DEC staff, environmental consultancies and community groups.
- Scanned 1000 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 adequate and authoritative inventory of the plant biodiversity of Western Australia.
- The collections are drawn upon constantly by DEC 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 5000 type specimens in the collection for the Global Plants Initiative.
- Continue to maintain the collection to an authoritative standard for all users.

FloraBase and 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 DEC'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 DEC's biodiversity data to the internet using standards-compliant web services and data structures.

Summary of progress and main findings

- Completed and deployed ImageBank, a major overhaul to the way the Herbarium image collection is managed.
- Completed migration of core herbarium databases and web applications to new and more reliable server hardware.
- Maintained FloraBase, World Wide Wattle and BioCase web services, correcting problems reported and enhancing delivery of information.
- Progressed development of new systems for maintaining plant descriptions in FloraBase.

Management implications

- FloraBase allows the community and DEC staff to retrieve the most recent information on the name, features, status and distribution of the 13481 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.
- Deliver taxon descriptions from a wide range of sources.
- Add new content, including interactive keys for identification of plant groups at species level.
- 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* (primarily in the genera *Conostephium*, *Leucopogon* and *Melichrus*) 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

- One paper on genus *Monotoca* published in *Nuytsia* in which a Priority taxon was described, the sole remaining member of the genus in Western Australia.
- A collaborative paper dealing with the genus *Astroloma* published in *Nuytsia*. Four new species described, two having conservation significance.
- A new paper providing a taxonomic update of the genus *Conostephium* has been submitted to *Nuytsia*. This includes descriptions of four new species.
- Fieldwork undertaken and manuscript drafted for a new paper describing three new species in *Melichrus*, a new generic record for Western Australia.
- Collection and redetermination of epacrid specimens in the Western Australian Herbarium, improving the standard of identification in the collection and veracity of FloraBase output.
- Three new phrase-name taxa in *Leucopogon* (*L.* sp. Cape La Grand, *L.* sp. Karroun Hill and *L.* sp. Varley) were added to the Western Australian Census.

Management implications

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

Future directions (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 *Cochlospermum macnamarae*, a rare, new and significant species from the Pilbara has been published in *Nuytsia*.
- A paper transferring a number of Western Australian species of *Ozothamnus* to *Pithocarpa* has been published in *Nuytsia*, resolving a long-standing anomaly in the taxonomic treatment of these genera.
- A short communication sinking the phrase-named species *Hibbertia* sp. Mount Lesueur into the widespread *H. crassifolia* has been published in *Nuytsia*.
- A paper describing as new the species previously phrase-named as *Hibbertia* sp. Gngagara has been prepared for submission to *Nuytsia*.
- Several new putative taxa in *Hibbertia* have been added as phrase names to the Western Australian Census following a taxonomic review of the herbarium's collections of that genus.

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.

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.

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. ileticos* species complex, *Cynoglossum*, *Grevillea curviloba* and *Grevillea evanescens*.
- Update weed data for collections in the Western Australian Herbarium.

Summary of progress and main findings

- Paper describing *Grevillea* sp. Gillingarra has been prepared and the species has been listed as Critically Endangered.
- The species *Picris compacta* has been listed as presumed extinct.
- Paper detailing native Western Australian plants as weeds published.
- Paper reviewing *Calystegia* in Western Australia published.
- Paper documenting the occurrence of Scotch broom in Western Australia published.
- Weedy populations of native species listed for removal from native ranges have now been included on FloraBase.

Management implications

- Recognition of *Grevillea* sp. Gillingarra has enabled assessment of its conservation status and it is listed as Critically Endangered.
- The example of *Salsola australis* originally considered to be a widespread weed and now found to be comprised of mainly native species highlights the need to carefully review identifications when listing species as weeds to be targeted for eradication.

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 nominated as Threatened Flora.
- Taxonomy of *Lambertia orbifolia*, *Banksia brownii* and *Grevillea curviloba* 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 accepted for publication in the journal *Heredity*, and a second manuscript on gene flow in *A. woodmaniorum* has been written.

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.

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 (187 genera) extended with further binary keys to species.
- Binary keys to species of the following genera reformatted and submitted to KeyBase: *Actinobole*, *Adenostemma*, *Angianthus*, *Arctotheca*, *Argentipalium*, *Asteridea*, *Bidens*, *Blennospora*, *Blumea*, *Brachyscome*, *Calocephals*, *Calotis*, *Carduus*, *Centaurea*, *Centipida*, *Chrysanthemum*, *Hibbertia*, *Minuria*, and *Pluchea*
- Paper describing new species of *Pleurocarpaea* published in *Nuytsia*.
- Paper describing *Pilbara* (a new genus) and *P. trudgenii* (a new species) published in *Nuytsia*.

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)

- Prepare further papers on taxonomy of *Olearia* and several new related genera.
- Complete the interactive key to Western Australian *Olearia* species for incorporation in FloraBase.
- Complete a revised treatment of *Olearia* for a new edition of *Flora of South Australia*.
- Reformat remaining binary keys to species within the Western Australian Asteraceae and submit to KeyBase.

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 taxa are currently recognised in the Eremaean and Northern Botanical Provinces of Western Australia; including 27 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

- Seven new taxa were added to WACensus, three of which are endemic to the state.
- WACensus was updated to remove *T. clelandii* ms and *T. bidwillii* as they do not occur in Western Australia; to convert four manuscript names to phrase names; and to make two phrase names informal synonyms of published names.
- A paper describing the new species *T. oxalidea* was published in *Nuytsia*.
- A short communication clarifying the status and distribution of *T. bidwillii* was published in *Nuytsia*.
- A paper clarifying the status of *T. supina* and detailing three new segregate taxa identified through morphometric analysis has been completed.
- A paper providing a conspectus of *Tephrosia* in the Eremaean Botanical Province, including descriptions for 10 to 20 undescribed taxa, is in preparation.
- Three distinct forms were recognised in *T. sphaerospora* in Western Australia, one of which is endemic.
- One hundred and sixty five images of 20 taxa, including 12 which are currently undescribed, were added to *ImageBank*.
- All *Tephrosia* specimens in the Reference Herbarium had their 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, and to examine newly discovered species. Progress on writing papers describing new species.
- Hydatellaceae: published paper on fruit and seed structure of *Trithuria*; paper on germination and seedlings structure in *Trithuria* published; paper submitted on biogeographic history of *Trithuria* submitted; participated in preparation of interim recovery plan for critically endangered species *Trithuria occidentalis*.
- Poaceae: paper published on molecular phylogenetics of *Neurachne* and its close relatives, with an emphasis on the evolution of C4 photosynthesis, for which this is a good model research group.
- *Thysanotus*: continued fieldwork and laboratory work, with progress on preparation of papers. Poster presented at conference. Paper describing a new species was submitted.
- Bush Blitz surveys: field and laboratory work resulted in progress on taxonomic reviews of *Arthropodium* and *Tricoryne*. The grant has now concluded and the fieldwork completed. Paper preparation is underway.
- *Lomandra*: descriptions of new and revised species were prepared for planned papers.
- *Logania* (Loganiaceae): a review of variation in *L. serpyllifolia* has been completed with paper writing underway.
- *Brachyloma* (Epacridaceae): a draft paper of a taxonomic revision of a section of the genus has been internally reviewed and is being revised.
- Work continued on an interactive key for lichen genera. A representative collection of photos of Western Australian lichen genera is awaiting incorporation into FloraBase, and a procedure for doing this has been developed. Feedback has been received on the list of poorly collected lichen species previously prepared and categorisation of the threat status for each species is underway.

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.

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 taxa occurring in south-western Australia.

Summary of progress and main findings

- Targeted, collaborative field work with local conservation officers, herbarium volunteers and staff at the Threatened Flora Seed Centre has improved our understanding of the distribution and conservation status of the potentially threatened microgeophyte *S. rubricalyx*.
- Popular articles were written for *LANDSCOPE* (Spring 2012) and *Australian Plants* (June 2013); and an information sheet was written.
- A revision of *S. junceum* and allies has been drafted.
- Fact sheets for several species have been progressed.
- The Stylidiaceae types at the Western Australian Herbarium have been annotated for the Global Plants Initiative scanning project.

Management implications

- Collaborative field work has enabled on-ground training of survey botanists, resulting in improved knowledge of a potentially threatened triggerplant, as well as the collection of seed for the Threatened Flora Seed Centre.
- Ongoing taxonomic studies continue to underpin conservation efforts in Western Australia, where a high proportion of triggerplants are rare or poorly known.

Future directions (next 12 to 18 months)

- Complete taxonomic papers on focus groups.
- Progress interactive key, fact sheets and phylogenetic research.

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

- Continued generation of descriptions and illustrations for the book *Marine Benthic Flora of North-western Australia*. The majority of the text has been written and edited/formatted by ABRS in readiness for publication in late 2013.
- Participation in a field survey (by PhD student R Dixon) of several central and offshore Kimberley locations, resulting in numerous new collections that have included several new taxa, including a new genus in the Sebdeniaceae, and many species newly recorded for Western Australia (e.g. *Gibsmithia larkumii*). In addition, several hundred specimens have been added to the herbarium holdings.
- Most recent collections are also represented by material suitable for DNA sequence analyses, many of which have been already been sequenced as part of the 'International BarCode of Life' project.
- Major papers concerning several aspects of the north-western Australian marine flora and further revisions to the red algal family Liagoraceae have been published. Papers incorporating significant revisions of the genera *Halymenia*, *Sargassum* and *Amphiroa* have been published, and a major paper revising *Caulerpa* has been accepted for publication. A manuscript describing historical algal collections from the Kimberley has been submitted.

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)

- Publication of papers describing new and existing genera, species and other categories; contributions to FloraBase.
- Finalise production of the *Marine Benthic Flora of North-western Australia*, to be published by the Australian Biological Resources Study as part of their *Algae of Australia* series in 2013.

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 upcoming book *Marine Benthic Flora of North-western Australia*. These will be uploaded to FloraBase once the book has been published.
- Numerous additional *in situ* and microscopic images of marine algae have been taken, these will be uploaded to FloraBase as soon as proposed changes to the site are complete.
- 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 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 the monitoring of the 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.
- Monitoring of the *P. cinnamomi* eradication site in Cape Arid National Park continues to indicate successful eradication two years post-treatment. Recent sampling in April 2013 has demonstrated that the *in situ* fumigation of the infested zone and localized vegetation destruction has resulted in no recovery of the pathogen across the treated area.
- The containment strategies deployed at Bell Track and Pabelup Drive within the Fitzgerald River National Park are still containing 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.
- Presented outcomes of the containment and eradication projects at two conferences and three industry workshops.
- Published three papers in international journals, another currently submitted.
- Published major research and management outcomes from DEC's Specific Nature Conservation Projects covering 2006–2012.

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.
- Undertake experiments into factors that increase the risk of *P. cinnamomi* spread and the establishment of new disease loci.
- Investigate the impact and management of other Phytophthora species within Western Australian native plant communities.

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, C Wilkins, 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 more than 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

- Papers describing a new, potentially threatened species of *Cochlospermum* from the Pilbara and a new, rare and range-restricted *Tetralthea* from the Goldfields were published in *Nuytsia*.
- A new subspecies within the critically endangered *Pityrodia scabra* was described in *Australian Systematic Botany*.
- *Hibiscus panduriformis* was newly added to the Western Australian Plant Census and recommended for conservation listing following identification of material collected during surveys associated with a mining proposal in the eastern Kimberley. An article recommending the removal of *Gunniopsis* sp. Fortescue (ME Trudgen 11019) was published in *Nuytsia*.
- Taxonomic assessment of specimens collected during surveys in the Fitzgerald River National Park has resulted in the recognition of new phrase-named taxa in *Hibbertia*, *Lasiopetalum* and *Leucopogon*.
- A paper summarising the achievements of this strategic taxonomy initiative has been drafted for submission to an international journal.

Management implications

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

Future directions (next 12 to 18 months)

- Assess and formalise the taxonomy of new Western Australian plant taxa, particularly those of conservation significance.
- Conduct field studies on poorly collected and taxonomically difficult species groups.
- Add and remove taxa from the Western Australian Plant Census as required, and make recommendations regarding the appropriate conservation listing of Western Australian plants.

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, DEC 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 will be 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

- The available illustrated key to all Western Australian species of the family *Goodeniaceae*, including important genera such as *Goodenia*, *Dampiera*, and *Lechenaultia*, has been updated and corrected following feedback from users.
- A combined key to all species of *Proteaceae* in Western Australia (including genera such as *Grevillea*, *Hakea*, *Petrophile* and *Isopogon*) has been completed and made available to users.
- A key to all Western Australian species in the family *Haemodoraceae* (which includes the kangaroo paws and the large and diverse genus *Conostylis*) has 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*) is under development and is nearly ready for user testing.
- A key to all Western Australian species of the difficult family *Restionaceae* 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.
- Complete key to *Lamiaceae* and make available to users.
- Complete draft key to *Restionaceae* for testing.

Conservation status and systematics of Western Australian *Acacia*

SPP 2003-008

Team members

B Maslin

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.

- Paper published describing *Acacia bartlei*, a new species from near Esperance.
- Manuscript submitted for publication to *Nuytsia* describing (1) *A. gibsonii*, an new species of conservation significance from east of Hyden, and (2) 13 new species of *Acacia* from the Kimberley region of Western Australia. Also, two papers in press with new *Vachellia* and *Senegalia* combinations for South East Asia and China, and South Asia and the Arabian Peninsula.

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)

- Undertake taxonomic study of new *Acacia* species for the Eremaean Province and South West Botanical Province.
- Complete taxonomic revision of *A. saligna*.

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 on the influence of habitat fragmentation and mating system variables on reproduction and progeny fitness in *B. sphaerocarpa* has been published in *Biological Conservation* and another paper detailing the genetic structure in the *B. sphaerocarpa* study area is in preparation.
- In *B. sphaerocarpa*, plants in eight small, highly fragmented populations had much less effective mating systems than in a large, relatively unfragmented population, in terms of a

population's capacity to persist. The results also suggest that the effect of linear population shape on the mating system and pollen dispersal is often underestimated. Changes in the mating system caused by population fragmentation, and in particular population linearity, are significantly correlated with reduced seed weight, seed germination, seedling growth and survival. The reduction in progeny fitness will reduce the viability of many population fragments.

- Paper on the impacts of fragmentation on pollen dispersal and genetic diversity in *Calothamnus quadrifidus* ssp. *teretifolius* has been accepted 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.

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.

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*, genetic diversity in *E. wandoo* and genetic diversity in *C. quadrifidus*.
- Finalise papers on genetic diversity, pollen dispersal and mating systems in *Hakea oldfieldii* and *Banksia nivea* ssp. *uliginosa*.
- Finalise papers on reproductive biology and demography in *H. oldfieldii* and *B. nivea* ssp. *uliginosa*.

Translocation of critically endangered plants

SPP 2001-004

Team members

L Monks, R Dillon, D Coates

Context

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

Aims

- Develop appropriate translocation techniques for a range of Critically Endangered 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 14 Critically Endangered plant species.
- Monitoring was undertaken for 62 sites of 38 taxa translocated in previous years.
- Collation of flora translocation data from across DEC has been completed and a meta-analysis of these data has commenced. Two publications based on these data are in preparation: one an overview of translocation outcomes in Western Australia and the other a review of translocation methods.
- Assisted DEC 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 DEC 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 confidentially 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 DEC 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.
- Prepare for publication *Acacia* translocation success study.

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, S 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 on temporal and spatial patterns of mating system variation in *Banksia cuneata* has been published in the *Australian Journal of Botany*.
- 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 range.
- Data analysis on year one mating system variation in two sister triggerplant species (*Stylidium affine* and *Stylidium maritimum*) with contrasting breeding systems has been completed and a paper presented at the Ecological Society of Australasia Conference in Melbourne 2012.

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.
- The mating system studies on *Banksia cuneata* indicate increased fluctuations in outcrossing rate over the years following habitat disturbance and suggest that temporal stability in the mating system may be a significant factor when considering the effects of habitat disturbance on plant populations. Spatiotemporal mating system variation warrants increased consideration in the design and establishment of success criteria in ecological restoration and 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.

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*.
- Complete seed collections from populations for year two of the study on the mating system in two *Stylidium* species, complete data analysis, and prepare a paper for publication.

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

- Continued monitoring the recovery of the Critically Endangered eastern Stirling Range Montane Heath and Thicket community from fire.
- Contributed initial findings of the Montane Heath and Thicket community study to a book chapter describing long-term trends in Australian heathlands.
- Continued monitoring the demography of the Critically Endangered *Verticordia staminosa* ssp. *staminosa* in relation to climate change.

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)

- Write up and publish research on the fire ecology of the eastern Stirling Range Montane Heath and Thicket Community.
- Continue monitoring *Verticordia staminosa* ssp. *staminosa*.

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 'Relationships between *P. cinnamomi* necrotic a asymptomatic lesion development' published.
- Papers on variation in susceptibility to *P. cinnamomi* within *Banksia* and threatened flora published.
- Database of 200+ taxa updated.
- Provisional susceptibility list distributed within DEC.

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.
- Determine variation in susceptibility of four *Banksia* species across a climate gradient on the south coast.
- 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, S Dudley, D Coates

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

- 220 seed collections lodged at the Threatened Flora Seed Centre (163 Declared Rare Flora [DRF], 21 Priority Flora and 36 common), including collections from five rare and threatened flora, processed and incorporated into the seed bank.
- Total number of collections stored in the Threatened Flora Seed Centre is now 3853 (1904 DRF, 992 Priority and 957 common).
- 77% of DRF and 22% of Priority taxa are now in storage in the Threatened Flora Seed Centre.
- 47 collections cleaned and stored (28 DRF, 9 Priority and 10 common collections).
- 33 germination tests conducted (24 DRF, 2 Priority and 7 common collections).
- Provision of germinated seeds for translocation of 16 Critically Endangered species.
- Continued collaboration with Kew's Millennium Seed Bank Project through the Australian Seed Bank Partnership.
- Paper published on seed viability constraints in *Eucalyptus erythrocorys* (Myrtaceae) and *Xanthorrhoea preissii* (Xanthorrhoeaceae).
- Paper published overviewing seed conservation achievements and future directions in the department.

Management implications

Provision of seed biology and ecology data will increase the success of recovery of threatened flora, particularly through translocation programs, and improve conservation of threatened and endemic Western Australian flora.

Future directions (next 12 to 18 months)

- Germination testing, storage and monitoring of existing collections.
- Ongoing research into seed biology and seed storage behaviour of threatened plant taxa.
- Provide seed storage and seed testing service for the Jandakot 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

New version of the key, WATTLE2, now deployed on the web and available via the Lucid Central website.

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)

- Provide web-based link to descriptive information and images for each taxon included in the web version of the key.
- Connect taxon names in WATTLE2 key to the revised and new taxon descriptions that reside on the ABRS Flora Online server.

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, K Shepherd, R Butcher, K Thiele, R Binks

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

- Analysis of genetic diversity in disjunct populations of *Eremophila microtheca* and *E. rostrata* has shown significant population structure within each species, 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.
- A journal paper describing two subspecies in *Pityrodia scabra* was published in *Australian Systematic Botany*. *Pityrodia scabra* ssp. *dendrotricha* nov. (previously *P.* sp. Yilgarn) is listed as a taxon of conservation concern and *P. scabra* subsp. *scabra* is Critically Endangered.
- A paper detailing the most variable gene regions for phylogeographic analysis was published in *Australian Journal of Botany*.
- 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 submitted to *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.

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* will assist in determination of sub-specific taxa and clarification 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.
- Assessment of genetic diversity and genetic structure will provide information to ensure the long-term maintenance of genetic diversity in *Lepidosperma* sp. Parker Range and *L.* sp. Mt Caudan during mining operations in the Parker Range.

Future directions (next 12 to 18 months)

- Analysis of *Eremophila microtheca* and *E. rostrata* will be completed and morphological assessment will be undertaken for *E. microtheca*.
- Taxonomic revisions of *Platytheca* sp. Sabina, *Hakea* aff. *prostrata*, and *Hydrocotyle scutellifera* and associated taxa will be completed.
- Combined analysis will be completed for *Lepidosperma* sp. Parker Range and *L.* sp. Mt Caudan.
- Identification of taxonomic entities in the *Synaphea* complex of the Pinjarra Plain will be completed.

LANDSCAPE CONSERVATION PROGRAM

PROGRAM LEADER: LACHIE MCCAW

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

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 the development of ecologically sustainable forest management practices. 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 individual was since detected in 2006 and 2012 and two in autumn 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 decline of ngwayir to almost undetectable levels has now occurred across the entire Upper Warren Region. The ngwayir population in the Upper Warren was the largest known population; it is genetically distinct and had higher genetic diversity than Bunbury and Busselton populations.
- Collation and validation of data from previous trapping and spotlighting is complete and up-to-date. Analyses and preparation for publication are underway, beginning with medium-sized mammal responses to timber harvesting.
- Two papers on retention forestry have been published that include Western Australian forest management practices in an international context (Gustafsson et al. 2012; Lindenmayer *et al.* 2012).

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.

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.
- A review of this project will be informed by the analyses currently underway.

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 DEC management interventions in maintaining and improving conservation values can be evaluated.

Summary of progress and main findings

- In 2012, LCI monitoring and evaluation sites in the King Leopold and Mitchell River national parks were re-sampled, and new sites established at two locations in the Prince Regent National Park, at Mount Trafalgar and Cascade Creek. Plans in 2013 are to expand the LCI monitoring and evaluation network into Drysdale River National Park and the Bachsten Creek/Mount Elizabeth area.
- DEC continues to develop monitoring partnerships with indigenous traditional owner groups including the Wunambal Gammlera, the Ballangara and the Willingan Aboriginal Corporations. Partnerships with other groups undertaking biodiversity monitoring activities in the region are being developed.
- Mammal abundance and richness in the North Kimberley is stable or improving relative to historical survey records from 1981–1982, 2003–2004 and 2007–2010. The diversity and abundance of mammals was much lower in more inland areas of the Mitchell River National Park, where cattle density is higher and the incidence and frequency of fire since 2000 has been greater.
- Populations of brush-tailed rabbit rat (*Conilurus penicillatus*) and golden-backed tree rat (*Mesembriomys macrurus*) have increased in areas where cattle have been culled over the past four years. This is strong evidence of negative effects of cattle on these species. Resurgence of *C. penicillatus* appears to be restricted to areas with older growth woodlands with high tree-hollow density.

- No obvious relationship was found between vegetation ground cover, time since fire and critical weight range mammal diversity or abundance, despite theoretical predictions. This suggests that site-specific vegetation attributes have little direct influence on mammal abundance. Larger-scale landscape attributes, for instance the pattern of unburnt patches over tens of kilometres, may have greater influence on site specific abundance.
- Dingoes were common throughout the King Leopold and Mitchell River national parks, irrespective of mammal abundance. This suggests that dingoes do not have a strong negative impact on small mammal populations, and in fact may have a net positive effect through suppression of cat predation. Few cats were recorded in either park, although they were seen more often at sites in the southern part of Mitchell River National Park where mammal abundance and diversity was lower.

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 be continued so that the effectiveness of management interventions can be evaluated.
- 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.

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

SPP 2011-020

Team members

L McCaw, B Ward, R Robinson

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 50000 ha 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

- Re-measurement of the thinning experiment in the 1972-regenerated forest at Warren block was completed in 2012.
- The incidence and severity of *Armillaria* root disease at the Warren experiment was measured.

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 utilize forest biomass for their survival and in doing so impart some form of damage to leaves, shoot, roots, stems or branches. There are 10 recognized 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 dryer 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 the invertebrate pest, including quantitative population surveys and host/environmental impact studies where appropriate and/or possible.
- Application of appropriate technologies including GIS and remote sensing.
- Liaise with local land users and general public.

Summary of progress and main findings

- More than 250,000 ha of forest was defoliated by GLS in 2010/2011. Populations have since decreased from this peak but still remain much higher than the 1992–2009 non-outbreak period. In 2012/13 high levels of defoliation by GLS were concentrated in areas between Muir Highway and south of Bevan Road.
- Pheromone trapping of GLS has been extended and was used to determine the 2012/13 population level. Data are being processed.
- A paper on the use of pheromones to trap adult moths was published in *Australian Forestry*.
- All FORESTCHECK monitoring grids were surveyed for JLM in October 2012. JLM population levels are low in Donnelly and Blackwood Districts and higher between Collie and Dwellingup. Population levels north of Collie are patchy. JLM is largely absent from forest north of Dwellingup.
- A paper summarising the last decade of JLM monitoring was drafted and submitted to *Conservation Science*.
- A departmental property near Badgingarra planted to *E. camaldulensis* was inspected for the presence of insect pest species and a report of the inspection drafted. Galls and the psyllid *Glycaspis sp.* were present.

Management implications

- Pheromone trapping is effective in monitoring GLS populations and could be incorporated into management practices as an early warning system for GLS outbreaks.

Future directions (next 12 to 18 months)

- Refine relationship between pheromone captures and larval numbers for GLS, and develop quantification of leaf area index and relate this to GLS population levels.
- Further develop the relationship between defoliation rates, leaf area index and satellite imagery.

Fire regimes and impacts in transitional woodlands and shrublands

SPP 2010-011

Team members

C Yates, C Gosper, 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 largest and most intact area of contiguous temperate woodland remaining on Earth. 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 woodland 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). The 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 under SPP 2009-005 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

- Development of a method to robustly estimate stand time since fire in gimlet (*Eucalyptus salubris*) woodlands that have not been burnt since prior to the period covered by remotely-sensed imagery.
- Investigate the effects of time since fire on the assembly and recovery of gimlet woodland plant community composition and development of ecosystem structure.
- Measure fuel dynamics with time since fire in gimlet woodland, mallee and *Allocasuarina* shrubland.
- Investigate pathways to weed invasion in the GWW.

Summary of progress and main findings

- A multi-century chronosequence of time since fire was established in gimlet woodlands using the modelled relationship between tree diameter and the number of annual growth rings. A manuscript from this work was published in the *Australian Journal of Botany* and a Science Division information sheet published online.
- Plant community composition in gimlet woodlands changed over the multi-century chronosequence. Diversity was high shortly after fire and also when long-unburnt, but lower over the intervening period, driven by maximum competitive influence of community-dominant trees and shrubs over intermediate periods post-fire. A paper from this work is in press with the *Journal of Applied Ecology* and a Science Division information sheet was published online.
- Floristic data, summary information on survey methods and results, and site photographs for all plots across the gimlet time-since-fire chronosequence were published in the public domain through the NatureMap portal.
- Structural changes in gimlet woodlands across the multi-century time-since-fire chronosequence indicate maximum community flammability at intermediate times since fire. A manuscript arising from this work has been submitted to a scientific journal and is in review.
- Visual fuel assessments using Project Vesta methods were conducted at 24 sites across the gimlet time since fire chronosequence. Strong correlations between visual assessments and detailed quantitative measurements indicate that visual assessments can usefully assess changes in fuel. A manuscript from this work is has been submitted to a scientific journal and is in review.

Management implications

- The research will inform ecological fire management that will benefit the outstanding natural values of the GWW.
- The relatively short time-series satellite imagery is inadequate for describing fire history and guiding landscape fire management in *Eucalyptus* woodlands. The research provides a multi-century chronosequence of woodland succession. There is no support from these community-level measures for *E. salubris* woodlands requiring recurrent fire to maintain plant diversity. An increase in the frequency of intense stand-replacing fires at intervals of <200 years would have adverse implications for biodiversity conservation. Large areas of regenerating woodlands will be passing into a stage of post-fire development with higher cover of some fuels over the coming decades. These may become vulnerable to fire return frequencies of less than <200 years under the influence of climate change.

Future directions (next 12 to 18 months)

- Complete through to publication the manuscripts on changes in vegetation structure with time since fire and visual fuel assessment in gimlet woodlands.
- Add new material to NatureMap on vegetation composition change with time since fire.
- Complete analyses of relationships between alien plant occurrence across the Great Western Woodlands and environmental factors, and produce a report and journal publication.

Fire, fragmentation, weeds and the conservation of plant diversity in Wheatbelt nature reserves

SPP 2009-005

Team members

C Yates, C Gosper, S Prober (CSIRO)

Context

Application of an ecological approach to fire management in DEC-managed conservation reserves, encompassing some 612 nature reserves confronting multiple threatening processes, is a significant operational and scientific challenge. Progress is being made in this area, but it is acknowledged that the lack of scientific information on fuel accumulation rates and fire behaviour for major plant communities, and the relationships between fire and the biota in the region, is a limiting factor. Moreover, because many reserves are small (median size 116 ha) and isolated, there are real concerns that prescribed fire regimes will act synergistically with other threatening processes and have undesirable consequences for the native biota in the longer term. For example, some fire regimes may reduce the resistance of native plant communities to invasion by non-native annuals that are abundant in the surrounding landscape. Yet there is a danger that biodiversity will be lost regardless, because of a lack of any fire management.

Aims

- Characterise current fire regimes in remnants of native vegetation in the wheatbelt, and determine how these relate to landscape context, such as remnant size.
- Identify the upper and lower limits of the fire interval needed to maintain diversity in plant communities in vegetation remnants.
- Investigate how current fire management methods, such as chaining and burning, affect native plant communities.
- Determine whether fire and other disturbances interact to reduce resistance of eastern wheatbelt plant communities to weed invasion.

Summary of progress and main findings

- Plant functional types (PFTs) defined by fire response traits were found to be useful for predicting and generalising vegetation changes with time since fire in mallee-heath, a shrubland community dominated by serotinous non-resprouting species. The predictive ability of PFTs in mallee, a community dominated by serotinous resprouters, was lower. A paper from this work was published in the *Journal of Vegetation Science* and a Science Division Information Sheet was published.
- Measurement of vital attributes (mortality and fecundity) for selected species with contrasting fire life-histories showed that some serotinous species take 20–30 years post-fire to accumulate a substantial seed bank, but some obligate seeding species have high mortality in long-unburnt vegetation. However, variability between populations rendered some estimates of acceptable fire intervals of limited practical value. A manuscript from this work was published in *Ecological Applications*.
- A summary of the project outcomes is in press at *Australasian Plant Conservation*.

Management implications

- Fire return intervals differed markedly with landscape context, with shortest intervals in contiguous vegetation in the Great Western Woodlands, longest intervals in small wheatbelt remnants, and large wheatbelt remnants having intervals of an intermediate length. This analysis demonstrated that fire regime-related threats to flora differ based on landscape context, necessitating different management approaches.
- Plant diversity and vegetation structure in mallee-heath are fire-maintained; hence mallee-heath has lower resilience to large deviations from modal fire intervals. In contrast mallee communities are modified by fire but plant diversity and vegetation structure are resilient to long intervals without fire. Short intervals between fires will limit structural development, which, if affecting large portions of the landscape, may have substantial consequences for fauna and

carbon storage. As appropriate fire return interval ranges for mallee have a longer upper bound, active introduction of fire in mallee communities in remnants would be a much lower priority than for mallee-heath.

- Both mallee-heath and mallee have species with life-history traits that make them vulnerable to fire-return intervals < 25-30 years; thus reducing fire incidence in frequently-burnt landscapes (e.g. Great Western Woodlands) would be desirable. Mallee-heath contained several species that experienced significant mortality when long-unburnt, suggesting that these species will decline under long (>~ 90 years) fire intervals and that active fire introduction may be appropriate in small wheatbelt remnants where current mean fire return intervals exceed 100 years. Variability in life-history traits between populations suggests that sampling these traits prior to fire management interventions would improve conservation outcomes.
- Although fire in itself had little effect on weed performance, weeds thrived on nutrient-enriched edges of reserves with or without recent fire. Hence, any decision to introduce fire into reserves in fragmented landscapes must be underpinned by a thorough analysis of the risks to all biodiversity values and especially potential interactions with invasive species.

Future directions (next 12 to 18 months)

- Finalise site-based flora data to NatureMap and site details to the Scientific Sites Register.
- This project is complete.

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

- Permanent back-up tagging to identify all trees for long-term monitoring is progressing.
- Further sites have been identified for establishing additional trials in neighbouring Chandler Block, representing different thinning regimes and dieback status.

Management implications

- The project will provide scientific data and conclusions to evaluate key assumptions that underpin *SFM Guideline No.1*. The findings will be relevant primarily to jarrah forest areas that are managed for timber production in the presence of *Phytophthora* dieback, and some key elements will 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)

- Complete initial crown health assessment on the first six trials, and analyse data.
- Carry out eucalypt and mid-storey regeneration assessments.

Fire regimes and biodiversity decline in the Kimberley

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 (CWR) 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

- Small-scale fires were found to have little direct influence on the abundance of mammals and other fauna. However, changes in diet selection among predator/insectivorous mammals after fire, influenced by the removal of ground-layer vegetation, showed a trophic effect of fire on savanna food webs. Predators were more successful at catching and ingesting larger prey after fires. A paper examining top-down predation by cats and dingoes on mammals after large-scale fires was published in *Austral Ecology*.
- A paper examining the question of whether resource limitation due to fire is a tenable explanation for fauna decline was published in *Austral Ecology*.
- Few changes in the fauna of pindan woodland were detected after fire, despite large changes in vegetation structure. Species information, and lack of a response to fire among most groups, showed that fauna in this vegetation type does not differ from that in surrounding savannas, and that this fauna is relatively resilient to most fire regimes. Large *Ctenotus* skinks and larger rodents showed a preference for vegetation unburnt for four years or more.
- Despite *Callitris* being an indicator of low intensity fire regimes, this species does not appear to confer fire shelter to other fire sensitive flora or fauna. Although *Callitris* stands had different vegetation structure relative to surrounding savannas, they were not associated with a greater proportion of fire sensitive plants (obligate seeding, heath or vine thicket species), CWR mammals, large *Ctenotus* skinks or forest-associated ant species. *Callitris* stands are therefore

not useful foci for conservation of fire-sensitive flora or fauna in savanna landscapes. A paper presenting these findings is in press with the journal *Biotropica*.

Management implications

Persistence of CWR mammals will be favoured by fire mosaics with small burn patch size (<1 km²) 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 DEC 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 will be finalised in 2013/14.

Identification of seed collection zones for rehabilitation

SPP 2006-008

Team members

M Byrne, D Coates, S McArthur

Context

The Sustainable Forest 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

- Microsatellite loci for *Banksia sessilis* have been developed.
- Collections from 24 populations have been made throughout the species range and DNA extraction has been completed.
- Microsatellite loci for marri, *Corymbia calophylla*, 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 *Allocasurina 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 draft *Forest Management Plan 2014–2023*.

Future directions (next 12 to 18 months)

- Genetic analysis of phylogeographic patterns and genetic structure in *K. coccinea* and *A. humilis* will be completed.
- Analysis of genetic structure in *B. sessilis* and *C. calophylla* will be undertaken.

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 been incorporated in the *Forest Management Plan 2004–2013* 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 soils, macrofungi, cryptogams, vascular plants, invertebrates, terrestrial vertebrates and birds.

Summary of progress and main findings

- The 2011/2012 annual report for monitoring in Blackwood District was completed. Findings were presented at Bunbury in December 2012.
- Eight new monitoring grids (FC49–FC56) were installed in Donnelly District in February–March 2013.
- Monitoring of macrofungi, terrestrial vertebrates, invertebrates and coarse woody debris was conducted on the new Donnelly grids in autumn of 2013.
- Analysis of data from the 10-year monitoring period (2002–2012) was commenced in February 2013.

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.
- Continue analysis of data from the 10-year monitoring period (2002–2012) and prepare draft manuscripts for publication of 10-year results.
- Undertake spring monitoring of new Donnelly district grids; analyse and present results to Donnelly District.

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

SPP 2006-002

Team members

A Pinder, M Pennifold, K Quinlan

Context

The *Forest Management Plan 2004–2013* includes 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 addresses 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 2011 round of sampling were identified.
- Invertebrate identifications from all rounds of sampling (2005-2011) were made consistent.
- A Science Division information sheet on the ecological conditions of streams in the south-west forests was produced.
- A short article on the project was written for *LANDSCOPE* magazine.
- An analysis of biogeographic patterning of aquatic invertebrates in south-west forest streams was commenced in collaboration with scientists from CSIRO in Canberra.

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)

- Undertake sampling of streams in 2013, with a focus on those considered to be in minimally disturbed catchments, with a view to providing long-term data on the response of aquatic invertebrate communities to climate change.
- Continue to update fire and logging history for catchment areas.
- Complete and publish a paper on biogeographic patterning in aquatic invertebrate communities of south-west forests.
- Prepare outlines of further papers examining impacts of climate change and forest management.

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 prepared and circulated to expert reviewers prior to publication approval.

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)

- Manuscript on tree recovery and seedling regeneration to be submitted for scientific 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

- All biodiversity monitoring sites were re-assessed for the last time prior to review of the project.
- Programmed operational patch-burning was unable to be carried out by Frankland District due to weather and other constraints.
- Two additional sites in long-unburnt vegetation in London block were assessed.
- Fuel-age mosaic maps, including for Surprise east, were updated using satellite imagery.
- Invertebrate sampling was conducted on all grid locations, including newly installed grids.
- Progress was made on sorting and documenting invertebrate collections.

- Macrofungal sampling was completed on six of the London block grids.
- Vertebrate trapping was completed on most sites, including the recently installed sites.
- Vegetation assessment was completed on all sites.

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, is increasingly evident. Any benefits to higher order organisms may take longer to emerge.

Future directions (next 12 to 18 months)

- A data gap analysis will be undertaken, and where necessary, additional data will be collected.
- Aside from necessary gap filling, no further field work will be undertaken until the 10-year data analysis and review is completed.
- Invertebrate samples will be sorted in the laboratory and data validated and analysed.
- Ten years of data will be analysed and written up.

Management of environmental risk in perennial land use systems

SPP 2004-003

Team members

M Byrne, C Munday, 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 new plant species as environmental weeds, hybridisation with native species, and gene flow from cultivated populations into natural populations.

Aims

- Develop and implement procedures for management of environmental risk in the form of assessment and management protocols to be applied to all germplasm under development within the Future Farm Industries Cooperative Research Centre (FFI CRC).
- Disseminate information about these processes to a wide audience of land managers and research personnel to help reduce the risk to the native environment.

Summary of progress and main findings

- Three new weed risk assessments have been completed for exotic and native forage species and will be published online on the FFI CRC website; additional assessments are in preparation. The prioritisation of other species for weed risk assessment and the review of prepared assessments continued as required.
- Genetic risk assessment has been completed for five species at specific site locations.
- Contribution to the review of the national post-border weed risk management protocol has been completed. Involvement in national discussions on improvements to weed risk assessment continue.
- Two new species management guides have been completed and will be published on the FFI CRC website. An additional guide is in preparation.
- A paper describing the FFI CRC environmental risk strategy and the development and application of GRA was presented at the 18th Australasian Weed Conference in Melbourne.
- Paper on genetic identification of weedy populations of *Acacia saligna* in South Australia has been published in *Australian Journal of Botany*. The majority of naturalised populations in

South Australia reproduce predominantly by seedling recruitment and have their origin in native populations located around Esperance, Western Australia.

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 or newly developed cultivars becoming environmental weeds.
- The adoption of the genetic risk assessment process will enable the risk of genetic contamination and hybridisation to be assessed. 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 system development.

Future directions (next 12 to 18 months)

- Continue to work with FFI CRC research personnel to identify taxa for weed and genetic risk assessment and complete those assessments.
- Continue to produce individual management guides for key species with some weed potential but significant agricultural benefit for publication by the FFI CRC.
- Continue technical advice to FFI CRC researchers on weed issues, including incorporation of weed risk into FFI CRC publications.
- Publish information sheets on weed and genetic risk assessment.
- Publish research into flower and fruit production in *A. saligna*.

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, Goldfields Regional staff, G Liddel, 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 DEC's Goldfields Region, this project aims to reconstruct some assemblages of the original native mammal fauna on Lorna Glen, a pastoral lease recently acquired by DEC. 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 2012 as part of the Western Shield program was ineffective due to the high availability of live prey, particularly mulgara (*Dasyercus cristicauda*).
- As a result of good seasons (rainfall) and high prey availability, the feral cat population is increasing, and is now double the density of two years ago. Dog/dingo density remains low, and foxes are absent.
- Five feral cats were trapped and radio-collared prior to baiting to assist with measuring baiting effectiveness.
- A PhD project commenced to investigate interactions between dogs/dingoes and feral cats.
- Mulgara population size has declined since last year, but is still relatively high. Mulgara continue to be recorded across virtually all landform systems and in all ages of spinifex.
- The new fire management plan was implemented, including installation of fuel-reduced buffers around some fire management cells and some core ignition, with mixed success.
- A draft spinifex fuel model was developed and tested. This will simplify operational use of the spinifex rate of spread guide.
- The bilby population continues to increase slowly despite relatively high cat density.
- A manuscript has been prepared on the value of burrowing animals as ecosystem engineers.
- A paper was published on the use of observers on horseback to monitor bilby populations.

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)

- Report on effectiveness of feral cat baiting in 2010–2013.
- Write up trials of revised spinifex fuel model.
- Write up trends in mulgara population in response to seasons and introduced predator control.
- Expand the highly successful predator-proof compound.

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

- Frankland District burnt part of the Nuyts Wilderness to create a mosaic of burnt and unburnt forest patches. Previous analysis of data collected at Nuyts and in the Mt Roe National Park showed that the severe wildfire markedly reduced the heterogeneity of measured forest structural and habitat attributes. In contrast, structural heterogeneity is predicted to have increased following the recent prescribed fire at Nuyts.
- A large proportion of beetle morphospecies in this assemblage has been identified as closely related to the beetle fauna of the nearby Mt Roe National Park, and most have only been collected from a narrow niche within and between wildfire and mosaic fire regimes.

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)

- Complete the analyses and prepare final manuscripts on the response of the beetle species of the Nuyts Wilderness and Mt Roe National Park to different fire regimes across all three components of biodiversity (taxonomic, structural, functional).
- Prepare recommendations on future monitoring for selected short range endemic and declared threatened beetle species within southern forest communities across a mosaic of vegetation types and fuel age.
- Commence incorporating local invertebrate inventories into the state-wide BugBase inventory to allow the future meta-analysis of the fire ecology of south-west invertebrates.

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.

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 DEC 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 in the two treatment catchments and in the control catchment continued.
- A paper describing the hydrological response to declining groundwater levels and groundwater disconnection was published in the *Journal of Hydrology*.
- A Science Division information sheet describing the role of groundwater disconnection on streamflow decline in the standard-treatment catchment was published.

Management implications

- The strong relationship between the magnitude of vegetation reduction and the extent of groundwater rise can guide harvesting and silvicultural practices.
- The risk of increased stream salinity from current harvest and silvicultural practices is lower than with past practices because the prevailing drying climate and retention of more vegetation following harvest results in more subdued groundwater rise than observed in the past.
- Forest thinning to enhance water production is likely to be most effective where groundwater is connected to surface water. Where groundwater is disconnected, thinning will be most effective if the treatments ensure a sufficient rise in groundwater levels to enable and to sustain the connection between groundwater and surface water systems.
- Findings from this study can improve the accuracy of hydrologic models used to simulate streamflow responses to future climate change scenarios. Past modelling has not anticipated the magnitude of the amplifying effect of groundwater on streamflow generation and consequently could potentially underestimate the extent of the decline in streamflow in response to further rainfall decline.

Future directions (next 12 to 18 months)

- Continue monitoring of groundwater levels, streamflow, stream salinity and turbidity and rainfall, because the data provide a unique long-term record of the hydrological response of the jarrah forest to climate change.
- Remeasure forest density along fixed transects to determine forest regeneration response to the timber harvest and silvicultural treatments.
- Collaborate with other agencies to apply a hydrological model to the results of this study.

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

- Findings from this study were reported in a second Science Division information sheet.
- Revision of manuscript on effects of fire on soil carbon.

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.

Management of the Vasse–Wonnerup wetlands

SPP 1999-017

Team members

J Lane, A Clarke, Y Winchcombe

Context

There is a long history of mass fish deaths in the lowest reaches of the Ramsar-listed Vasse–Wonnerup wetland system. The incidence and severity of deaths can be reduced by timely openings of the entrance sandbar and two sets of floodgates. Careful management of flows and water levels is needed to prevent adverse impacts on conservation values and adjoining lands. Following a mass fish kill in 1997, the department led the establishment of an inter-agency technical working group to co-ordinate relevant agency activities. More recently, the Department of Water has taken an active role and interest in relation to fish kills and management of Vasse–Wonnerup. In 2013, DoW assumed leadership of the Vasse Estuary Technical Working Group pending a proposed six-month review of state and local government roles in waterways management in the City of Busselton. DEC has a continuing interest in Vasse–Wonnerup due to its conservation values and Ramsar Convention status, and makes an in-kind contribution through Science Division staff with relevant expertise and proximity to this wetland system.

Aims

Continuously monitor water levels in the Vasse and Wonnerup estuaries as these are key determinants of the ecological character and conservation values of the Vasse–Wonnerup Ramsar site.

Summary of progress and main findings

- Water levels in the Vasse and Wonnerup estuaries were continuously monitored during 2012/13, by means of data loggers.
- Provided technical and logistic support for research programs undertaken by Murdoch University.

Management implications

Vasse–Wonnerup is at risk of ecological collapse, with excessive nutrient levels potentially causing a shift in dominance from macrophytes to phytoplankton in aquatic plant communities, more toxic algal blooms, worsening odours, more frequent fish kills and fewer birds. The scientific research that is being undertaken primarily by Murdoch University with Commonwealth and regional NRM funding, and led by the Department of Water, is aimed at developing a better understanding of these problems and their relationship with water levels, water flows and salinities, and identifying affordable management actions to prevent or alleviate them.

Future directions (next 12 to 18 months)

- Future directions will depend on the outcome of the proposed six month review of state and local government roles and responsibilities with respect to management of waterways in the City of Busselton, including Vasse–Wonnerup.
- Continue to monitor water levels in the Vasse and Wonnerup estuaries using continuous water level recorders.
- Continue to provide technical and logistical support and guidance for management-related research by other organisations on Vasse–Wonnerup, as resources permit.

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 Wheatbelt wetlands in relation to threatening processes (particularly dryland salinity), 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: field component of 2012/13 monitoring was completed and databased. Archiving of samples from low priority wetlands has allowed some new wetlands within the Drummond and Buntine–Marchagee Recovery Catchments to be added to the program.
- All invertebrate samples up to 2011 now processed.
- Laboratory investigations to improve processing times of invertebrate samples have been instigated.
- A data report on trends in invertebrate communities at Lake Coyrecup and Lake Towerinning was produced.
- Waterbird communities were surveyed across the Warden Recovery Catchment/Ramsar wetlands and the Gore Ramsar wetlands in November 2012 and February 2013. 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.

- Results of additional sampling of aquatic invertebrates at Lake Bryde following a summer flooding event was reported to the Bryde Recovery Catchment.
- Completed identifications of specimens collected for a study to investigate hydroperiod requirements of aquatic invertebrate fauna in Drummond wetlands. An interim report of this was completed.
- Surface water monitoring: depth and water quality monitoring was undertaken at 101 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 installed on several wetlands with high conservation value that are under threat. High resolution oblique aerial photography was obtained for a number of wetlands in the Warren, South Coast and Wheatbelt regions.
- Vegetation monitoring for 2012 completed. An additional sampling of Lake Wheatfield in the Warden Recovery Catchment was undertaken to capture any response to recent management actions. Preliminary data suggests some recovery of vegetation associated with management intervention to reduce water levels and waterlogging of the riparian zone. Seedling recruitment has also been observed.
- Shallow groundwater monitoring and databasing was completed for the 2011/2012 sampling round. Long-term trends can now be determined from the data.
- Report presenting 1977–2011 depth, salinity and pH data for 101 currently-monitored wetlands was completed. A report on the biological monitoring results for Lake Bryde was prepared.
- A journal article prepared in collaboration with Natural Resources Branch presenting soil electrical conductivity data is currently in review with *Geoderma*.
- Vegetation monitoring data for 2011 was prepared for analysis, and databasing of vegetation monitoring data for 2012/2013 is underway.

Management implications

- Monitoring of depths, salinities and pH of 101 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 more towards the recovery catchments, where results can inform adaptive management, and other wetlands with high conservation value.
- Publish a review of the wetland monitoring component of the State Salinity Strategy.
- 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

- Monitoring experimental plots for the 15-year post-fire assessment was completed in December 2012.
- Two 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.
- Continue analysis of data from 15-year post-fire assessment.

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, and investigate the mating system and diversity in sandalwood.

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.
- *Acacia ancistrocarpa*—Phylogeographic analysis of populations was carried out using three chloroplast gene sequences. Haplotype diversity was moderate with most populations showing specific haplotypes. Nuclear diversity was analysed with an additional four loci to complete the data set. Analysis showed moderate diversity with little genetic structure across the Pilbara populations of this widespread species.
- *Acacia atkinsiana*—Phylogeographic analysis of populations was carried out using three chloroplast gene sequences. Haplotype diversity was low with little geographic structure. Nuclear diversity was low and genetic differentiation among populations was moderate in this Pilbara endemic species compared with its widespread congener.
- *Grevillea paradoxa*—Individuals from 20 populations have been sequenced at two chloroplast regions and genotyped with 14 nuclear microsatellite markers. Data analysis is being conducted.
- *Melaleuca nematophylla*—Individuals from 20 populations have been sequenced at two chloroplast regions and are being genotyped with nuclear microsatellite markers. Data analysis is being conducted.
- *Mirbelia bursaroides*—Germplasm collections have been conducted for 10 populations. Collections and DNA extractions are ongoing. A nuclear microsatellite library is being constructed.
- *Grevillea globosa*—Germplasm collections have been conducted for five populations. Collections and DNA extractions are ongoing. A nuclear microsatellite library is being constructed.

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.

Future directions (next 12 to 18 months)

- Genetic diversity and phylogeographic patterns will be investigated in four more species in the Pilbara.
- Phylogeographic and genetic structure will be investigated 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 in 2012.

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)

Continue analysis of the 2011/2012 data from the Warren thinning experiment.

MARINE SCIENCE PROGRAM

ACTING PROGRAM LEADER: KIM FRIEDMAN

The broad goal of the Marine Science Program is to ensure DEC'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 ecology of the Ningaloo Marine Park 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.

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

- Understanding the processes that govern spatial and temporal variation of macroalgal abundance provides a basis for assessing the impacts of anthropogenic effects on macroalgae and determining when management intervention may be appropriate. This study found that sea temperature is an important driver of macroalgal biomass and diversity in the Ningaloo lagoon, whilst nutrients, light, wave energy and herbivory explained relatively small amounts of variation in macroalgal data. Changes to the environment due to anthropogenic activities that lead to pollution, increased sedimentation or removal of herbivores may change this scenario. The strong correlation between macroalgal biomass and temperature also suggests that changes in sea water temperatures will influence when and where macroalgae are most prevalent. As the macroalgal beds have previously been identified as an important nursery habitat, changes in the distribution of macroalgae due to climate change may have consequences for survival of juveniles and ultimately adult stocks.

- A manuscript documenting spatial and temporal differences in macroalgal biomass has been submitted for publication in an international journal.

Management implications

- Improved understanding of the spatial arrangement of macroalgal fields will increase our ability to predict distribution of algal biomass and diversity for spatial planning. This offers a baseline for future monitoring, evaluation and reporting of condition change in macroalgal communities.
- 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 and social values articulated in the Ningaloo Marine Park Management Plan and management plans for other tropical marine protected areas.
- Improved ability to predict future abundance of adult stock will contribute 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 where juvenile fish can be found, and the abundance of different sized adults has been collected for one summer. Further sampling over the next two years 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

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 and related social assets, 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. DEC'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 and sediment quality) across nine marine parks in Western Australia, extending from Walpole–Nornalup in the south to Rowley Shoals in the north.
- Individual status reports that include new and historical time-series information on multiple biophysical assets and passive social values (43 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.
- Development of more streamlined data management and audit processes, for managing work-flows and warehousing the WAMMP information needed to service Marine Park and Reserves Authority audits.

- Built collaborations with external data providers to augment WAMMP's biophysical data collection capability.
- Completed a time-series assessment of seagrass communities on behalf of the Cockburn Sound Management Council, which assessed new and historical information on the status of seagrass and the pressures that impact them.
- Scientific publication of monitoring data to describe coral bleaching across 12 degrees of latitude in Western Australia and historical changes to coral cover.
- Training of DEC staff, interns and volunteers on monitoring protocols for multiple biophysical assets (e.g. coral, fish, mangrove, Australian sea lions and coastal biological 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)

- Continue to publish documents that describe the foundations, framework and process components of the WAMMP program.
- Publish a series of guideline documents that describe the selection of condition, pressure and management response indicators, and the delivery of MER across Western Australia.
- 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 of 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 based on parameters and guidelines set in strategic DEC documents.
- Where possible, key datasets have been accessed and meta-data developed and incorporated into a marine data warehouse.
- Negotiations are in progress with industry and consultants to source further high-priority data.
- Annual report drafted for submission to Woodside Energy Ltd.

Management implications

This project will provide an improved understanding for government, industry and the local community of historical trends in the condition of marine biodiversity assets and human use of this region, and the effectiveness of past management programs. It will identify existing and potential issues and risks where future management action may be needed.

Future directions (next 12 to 18 months)

- Continue negotiations with data custodians to acquire high-priority datasets.
- Provide advice and recommendations to assist in the design and implementation of Pluto LNG Project Offset "d" projects (ii), (iii) and (iv).
- Ensure final data and meta-data storage solutions meet access standards.
- Ensure project outputs and outcomes are communicated to stakeholders, industry and the broader community.

North West Shelf Flatback Turtle Conservation Program strategic plan

CF 2011-118

Team members

S Whiting, H Raudino

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

- The submission for the NWSFTCP Advisory Committee has been completed and approved by Director General, and Minister for Environment and Premier. It is currently with Cabinet.
- A draft review of marine turtle research and monitoring has been completed.

Management implications

The key purpose of this plan for the NWSFTCP is to 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 long-term, robust monitoring programs and deliver management outcomes.

Future directions (next 12 to 18 months)

- *Conservation Plan for Marine Turtles in Western Australia* finalised and published.
- *Strategic Plan for the NWSFTCP* finalised and published.
- The NWSFTCP Advisory Committee and Panel of Experts are approved and operating.

WAMSI 2: Kimberley Marine Research Program

CF 2011-117

Team members

K Waples, C Simpson

Context

In June 2011, the Western Australian Government released the Kimberley Science and Conservation Strategy (KSCS), with its overarching aim to recognize and conserve one of the world's last great wilderness areas. 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 DEC 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. 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.

Aims

- Ensure the KMRP research projects are developed and delivered in line with the State's priority needs, and to meet DEC 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, resource managers and decision makers.

Summary of progress and main findings

- Development and review of 25 Science Project Plans based on approved Science Concept Plans. Of these, 21 Science Project Plans have been approved by the WAMSI Board, with the additional four to be further scoped in the 2013/2014 financial year.
- Project Agreements for seven of the projects have been fully executed, with an additional 12 in progress.

- Active engagement with the 14 Aboriginal Corporations along the Kimberley coast has been initiated. This process is well progressed towards developing partnerships with traditional owners prior to initiation of individual research projects.
- On-ground research has begun for three projects.

Management implications

Research will increase the 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. The program will also foster relationships with Aboriginal communities, enhancing joint management activities and capabilities.

Future directions (next 12 to 18 months)

- Prior, informed consent from traditional owners for research on country and development of partnerships, where appropriate.
- Initiation of the full set of research projects in the Kimberley.
- Communication activities to promote the KMRP Science Plan and suite of research to relevant marine resource managers as well as to local and Indigenous communities in the Kimberley.

WAMSI 1 Node 3: science administration, coordination and integration

CF 2011-116

Team members

K Waples, C Simpson

Context

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

The science plan for Node 3 of WAMSI consists of six main projects, each led by a different institution. Thus the coordination and administration role entails ensuring that all project plans are functioning according to the agreed outputs and timeframes. A key focus of this project is to ensure the transfer and uptake of knowledge generated through the research into DEC management policies, practices and actions. The latter element will become an increasing focus of this project as the research program progresses to completion in 2010, and the final synthesis report is developed for the wrap up of WAMSI in December 2011. As such, both communication and data management are critical elements in knowledge transfer and uptake and are being addressed through this program.

Aims

- Ensure the coordination and administration of the research program.
- Ensure the integration of this research program with other research within WAMSI and with external programs relevant to the Ningaloo Marine Park.
- Ensure the outputs of research undertaken through the NRP reach target audiences.

- Ensure that knowledge transfer and uptake occurs between scientists, resource managers and decision makers.
- Ensure the long-term storage and custodianship of data from the research undertaken.

Summary of progress and main findings

The WAMSI 1 Node 3 research program was completed in December 2011. Ongoing activities since that time include the continued promotion of the research findings and their application to management through operational activities in the region, through research and monitoring activities in the Marine Science Program and through provision of advice and information for review of the Ningaloo Marine Park Management Plan to the Marine Policy and Planning Branch and Marine Parks and Reserves Authority (MPRA). In particular, a report, presentation and extensive advice was provided to the MPRA for the Ningaloo Periodic Audit in December 2012.

Management implications

- A key role of this project was to ensure that outcomes of the research both within the NRP and from external research programs were reviewed and used in refining and updating management of the Ningaloo Marine Park through changes to policy, management activities and planning exercises where relevant. Specific implications for management came from each of the individual projects in the research program and will be implemented as appropriate over time.
- The development of a knowledge transfer and uptake framework will be instrumental in ensuring a similar process is followed for other research projects conducted by DEC.

Future directions (next 12 to 18 months)

This function is completed.

Regional-scale coral bleaching on Western Australian reefs

SPP 2011-008

Team members

S Wilson, J Moore, K Friedman, S Field, H Taylor, R Middlebrook, G Shedrawi, M Depczynski (AIMS), N Evans (Department of Fisheries), L Bellchambers (Department of Fisheries), J Gilmour (AIMS), B Radford (AIMS), T Ridgway (AIMS), D Thomson (CSIRO), R Evans, T Holmes

Context

In Western Australia, coral reefs are key assets and provide critical habitat for a large diversity of flora and fauna. Understanding ecosystem processes that have a key role in structuring asset assemblages in our marine parks is therefore critical if we are to effectively monitor and manage Western Australian reefs in space and time. Here, as is the case worldwide, coral reefs are under increasing threats from climate and anthropogenic stressors that are eroding the resilience of reefs to ecological change. During the 2010/2011 summer, a considerable ocean warming event occurred along approximately 1200 km of Western Australian coastline. Accumulated thermal stress over this period impacted coral reefs from the Dampier Archipelago to Rottnest Island and possibly further to both the north and south.

Aims

- Determine the dynamics of water temperature fluctuations during the warming event at local to regional scales.
- Quantify the spatial and temporal extent of coral bleaching across Western Australian coral communities.
- Investigate the post-impact response of reef corals to bleaching at local to regional scales.
- Inform future management strategies detailing responses to disturbance events, including refining of temperature thresholds for bleaching of coral reefs in Western Australian marine protected areas.

Summary of progress and main findings

- A paper on bleaching, coral mortality and survivorship on a West Australian fringing reef has been published in *Coral Reefs*.
- A paper on mass bleaching and loss of coral was published in *PLoS ONE*.
- Information on bleaching of Western Australian reef corals was written as a chapter in a Fisheries Research Report.
- Presentations were made at public fora in Perth and Exmouth.
- A poster was presented at the International Coral Reef Symposium in Cairns.

Management implications

Impact and response trajectories of coral communities across Western Australian marine parks to bleaching events will better inform management of the importance of temperature stressors to corals. These results will also inform future disturbance response plans and facilitate forward planning so that DEC is better equipped to assess disturbance events, such as bleaching, in a timely fashion.

Future directions (next 12 to 18 months)

This project is now complete.

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 typically 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 impedes 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 manuscript on morphological variation in the structure of monospecific mangrove stands in an arid World Heritage Area has been submitted to the journal *Estuarine and Coastal Shelf Science*, and a poster was presented at a conference on mangrove ecology and management in Sri Lanka.
- A paper on the algal community associated with mangrove pneumatophores in the SBMP 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.

Comparison of underwater visual census and diver-operated video methods for assessing fish community condition in tropical and temperate coastal waters of Western Australia

SPP 2010-010

Team members

S Wilson, T Holmes, M Rule, R Evans, K Friedman, G Shedrawi

Context

In shallow coastal waters, the condition of fish communities has traditionally been monitored using a technique known as underwater visual census (UVC). More recently, a technique for assessing finfish community condition has been developed that uses stereo-video to capture imagery of fish communities that is later analysed in the laboratory. Known as diver-operated video (DOV), this technique has potential advantages over UVC because sampling theoretically requires less scientific expertise, takes less time in the field, and data analysts have access to reference material to help identify fish. In addition, it provides a permanent record of the survey that can be checked or revisited at a later point if required. However, DOV datasets may be more costly to process and it is unclear if video imagery captures the same level of diversity and abundance as skilled divers conducting UVC.

Despite the significant amount of DOV surveys that have been completed on fish communities in Western Australia over recent years, no thorough investigation comparing the overall utility, results and cost-effectiveness of this technique with conventional UVC methods has been conducted. As such, comparable assessments need to be undertaken to assess the relative utility of these techniques in both temperate and tropical waters where the Western Australian Marine Monitoring Program (WAMMP) has monitoring responsibilities. This study will improve our understanding of historical UVC and DOV dataset compatibility and the relative costs of each method.

Aims

- Examine the comparability of the fish community dataset (diversity, abundance and size measures) resulting from collection using UVC and DOV survey techniques.
- Examine the effect of varying levels of diversity and abundance on the resulting fish community datasets when data is collected using the two techniques.
- Examine the effect of habitat complexity related to tropical and temperate marine ecosystems on the resulting fish datasets when data is collected using the two techniques.
- Assess the relative cost and practicality of both UVC and DOV techniques in the context of long-term monitoring programs in both tropical and temperate remote locations.

Summary of progress and main findings

- The study found that UVC consistently recorded higher measures of species richness and these differences were most pronounced at tropical locations where diversity was high. Differences in the characteristics of fish assemblages were primarily driven by UVC detecting more cryptic species. When examined at higher taxonomic or functional levels there was greater comparability between the assemblages recorded by each method, particularly in temperate locations. Data collected using stereo-DOV took 2–3 times longer to obtain than with UVC due to extensive post-processing time required by the stereo-DOV method. Overall, data collected by the two methods are most comparable in temperate locations, or when examined at higher taxonomic/functional levels. However, comparisons should be approached more cautiously in higher diversity locations, or when assessing at finer taxonomic resolution.

- Results from the Rowley Shoals were presented at the Australian Coral Reef Symposium.
- Results from the entire study were presented at the MSP science meeting 2012.
- A paper on the project has been accepted for publication in *Limnology and Oceanography Methods*.

Management implications

- Evaluation of each methodology, including cost and time analysis, will provide advice to monitoring programs on which methods are most appropriate for assessing diversity and abundance of fish in marine protected areas.
- Time series analyses allow managers to detect trends in the condition of assets within marine parks. Information obtained from this study will allow us to assess if comparisons between historical datasets collected using UVC are comparable with more recent data collected with DOV.

Future directions (next 12 to 18 months)

This project is complete.

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, J Moore, R Evans, K Friedman, J Huisman, 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 will involve 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

- Analysis of the digital imagery for both benthic and fish communities and satellite imagery of the dredge plume for the inclusion in the Gorgon MER Phase 1 final report.
- Gorgon MER Phase 1 final report drafted and internal review.
- Development of a summary meta-data report detailing all fieldwork that has been completed for Phase 1 of the project and summarising the data collected and the location of the data stored.
- Development of a databasing system to ensure the safety and security of all data collected through the Gorgon MER project. Backup and storage of all digital imagery.
- Planning for longer (5–10 year) term Gorgon MER activity to monitor the occurrence of long term impacts relating to the Gorgon dredging operations and ongoing marine construction activities adjacent to the MBIMPAs. Planning is being completed in cooperation with industry and other research groups completing research, monitoring and evaluation projects in and adjacent to the MBIMPAs.

Management implications

- The project provides DEC's managers and scientists with baseline information 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 DEC 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)

- Completion of planning and initiation of fieldwork for transition into longer-term strategic monitoring (Gorgon MER Phase 2).
- 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 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 DEC'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

- Three years of seasonal fieldwork for this project has been completed. All sample processing has been completed and the focus is now on identifying voucher specimens with the assistance of external experts. Over 120 species have been identified so far.
- A third annual survey of large bivalves inhabiting shallow sand flats of the WNIMP was completed in April 2013 with staff and students from Edith Cowan University, as part of an ECU/DEC undergraduate teaching collaboration. The data from these three surveys are currently being analysed.
- An information sheet has been published on benthic algae and seagrasses of the Walpole and Nornalup Inlets Marine Park.
- A manuscript on change in distribution of bivalves in the estuary has been prepared.
- A *LANDSCOPE* article was published and a second article is in preparation.

Management implications

- This study will determine 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 assist the implementation of long-term benthic invertebrate community monitoring by DEC's 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

- Three papers were published in *Coral Reefs, Conservation Biology and Marine Environmental Research*.
- Project information was contributed to the *Tropical coastal fish marine climate change impacts and adaptation report card for Australia*.
- Presentations were made at the WAMSI Climate Change Research Symposium, the International Reef Symposium in Cairns, and the Ecology and Management of Coral Reef Recovery Dynamics Conference in Townsville.

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)

- Publish manuscript on meso-predator fish.
- Complete analysis of turnover rates of meso-predatory fish.

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 DEC'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

- All species identifications have now been completed with the assistance of external experts and analysis of the spatial and temporal data has commenced.
- A paper examining broad spatial and temporal patterns in the intertidal invertebrate communities of the MMP and SIMP has been commenced.
- A paper examining patterns in the diversity of algae on intertidal reefs of the MMP and SIMP has been commenced.
- Compilation of a species guide to assist future monitoring of temperate intertidal reefs continued.
- An information sheet and a *LANDSCOPE* article were published.

Management implications

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

Future directions (next 12 to 18 months)

- Ecological papers from this study will be published.
- The species guide to assist future monitoring will be completed.

SCIENCE APPLICATIONS UNIT

MANAGER: PAUL GIOIA

A major role of the Science Applications Unit is to manage and make available the digital biodiversity assets of the Science 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

DEC, 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. DEC 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 DEC and the wider community.
- Maintain updated species databases and provide facilities for entering specimen label information.

Summary of progress and main findings

- Support has been provided to maintain fauna conservation status more effectively.
- Enhanced support has been provided for maintaining vernacular names, especially where several names are in use for the same taxon.
- Other minor bugs have been fixed and enhancements implemented as required.
- The distribution mechanism for Max has been updated to support Windows 7 and the changed DEC security environment.

Management implications

- The development of any database in DEC 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
- Fungi names are scheduled to be implemented within the 2013/2014 financial year.
- Reassess the feasibility of implementing the new fauna collecting book forms.
- Evaluate the future use of, and investment in, Max within the context of new data collection tools developed as part of the Atlas of Living Australia.

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

- The last 12 months have been focused on providing new or updated data content. Two major releases of NatureMap cumulatively included four new and updated themes, eleven new data sources, and sixteen new and updated reference layers.
- The new Great Western Woodlands (GWW) theme includes interactive maps modelled on the published GWW strategy, an overview of the GWW, the extent of previously mapped vegetation and fire ecology studies within the gimlet woodlands.
- The new Pilbara Threatened Fauna theme provides detailed profiles on selected species, including information on conservation status, distribution, images, habitat and relevant publications.
- The new Yilgarn Flora Surveys theme (previously the Banded Iron Formation theme) has been significantly widened in scope to include additional flora surveys within the Yilgarn craton. These surveys provide baseline information for assessing the conservation status of flora species within the context of mining and exploration activities.
- The Wheatbelt NRM Theme has been updated to include information from two substantial projects: 1) the consolidation of existing mapped vegetation from numerous projects into a single harmonised product; and 2) a structural and floristic classification of wheatbelt eucalypt woodlands, including detailed species fact pages.
- NatureMap recorded 342 new registrations over the last twelve months, bringing the total from 1178 to 1520, a 29% increase.
- The underlying software and hardware infrastructure that enables mapping and spatial analysis is being upgraded, resulting in a more stable and robust platform for NatureMap to continue operation into the foreseeable future.

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)

- Infrastructure upgrade is scheduled for completion by September 2013.
- New reference layers and species datasets will be added as they become available, with a particular focus on historical biological surveys conducted by DEC staff over the last thirty years.
- A project to spatially reference journal articles is targeted to commence in 2013/14, aimed at allowing published knowledge as well as raw data 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, S Hopper (University of Western Australia)

Context

The current DEC reserve acquisition and NRM 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. DEC 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 2004 analysis has been repeated and results compared with a 2012 snapshot for both species richness and endemism at a range of scales, enabling a comparison of sample effort and diversity patterns with the benefit of 10 years further data collection.
- Accumulation curves have been generated for each cell within the study area, creating a better understanding of how vouchering practices affect data comprehensiveness in different parts of the study area and providing a potential guide for future survey priorities.

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)

- Repeat the bio-regionalisation analysis on the 2012 snapshot using the same methodology as 2004.
- Repeat this analysis using all grid cells within the study area to assess the sensitivity of analysis results to site selection.
- Produce two manuscripts for review.

OBSERVATORY

MANAGER: ARIE VERVEER

Perth Observatory, established in 1896, is Australia's oldest continuously operating observatory. Perth Observatory is the only significant professional observatory between South Africa and the eastern states of Australia and is sought for collaborations with other astronomy institutions because of its capabilities and its particularly isolated location on the globe.

Astronomical outreach and education

CF 2011-102

Team members

R Martin, A Verveer, V Smith, A Williams, G Lowe, A Taylor

Context

The observatory's core function provides an outreach program to the public and education sector to experience the splendour of the night sky through a range of telescopes with experienced volunteers and an outreach coordinator. Additionally there is significant demand for astronomy education services from many groups and individuals within the community.

Aims

- Provide relevant and timely education services.
- Demonstrate science in action.
- Facilitate the development of the tourism potential of astronomy.

Summary of progress and main findings

- The number of visitors attending star viewing nights and day-time guided tours totalled 4949 for the year.
- Twenty-three lectures and presentations were made to university undergraduates, primary school students and community groups.
- Customer satisfaction surveys showed 99% of customers were satisfied with their visit or the service provided by the observatory, and 99% were satisfied with the educational quality of the services in which they participated.
- Progress on development of a day tour program based on the Australian education curriculum.

Activity Measures

Activity	2012/2013	2011/2012	2010/2011	2009/2010	2008/2009
Star viewing sessions	81	76	72	77	102
Night visitors	3928	3348	3461	3604	4334
Sunday guided tours	0	0	11	46	37
Daytime guided tours	1021	826	356	689	1131
Astronomy field nights	3	1	1	7	10
Field night attendance	3000	3500	3000	1488	1846
Lectures and talks	23	20	21	21	44
Talk attendance	4168	893	350	825	1294
Student consultations	0	0	0	2	25
Customer satisfaction (star viewing and guided tours, %)	99	98	98	97	98
Astronomy awareness raised (%)	99	99	97	100	100
Educational quality (%)	99	98	98	99	98

Management implications

The substantial visitor numbers, together with sound customer satisfaction evaluations, indicates that there is continuing strong demand for these services from the observatory.

Future directions (next 12 to 18 months)

- Recruit and train additional volunteers to take guided day tours.
- Enhance the night tour program with the establishment of a 76 cm visitor's telescope and dome.
- Establish a solar telescope for the day tour program.
- Establish a schools day tour program based on the Australian curriculum.
- Establish a higher educational program utilising an internet telescope.

Astronomical information services

CF 2011-101

Team members

R Martin, A Verveer, V Smith, G Lowe, A Taylor

Context

This core function involves providing information of direct use to various groups within the community. There is a significant demand for astronomical information from many different groups and individuals within the community.

Aims

Provide relevant and timely astronomical information.

Summary of progress and main findings

- A 1600% increase in the Facebook hit rate.
- Continuous updates of the observatory's website.
- Volunteers continuing cataloguing historical items at the observatory, including the book collection.
- A near doubling of the telephone enquiries.

Activity	2012/2013	2011/2012	2010/2011	2009/2010	2008/2009
Telephone enquiries	10400	5358 [*]	4972	8916	4817 [*]
Email enquiries	858	602	998	494	769
Consultations	9	12	0	9	38
Newspaper, radio & TV	135	132	116	109	129
www page views	162000	346000	260000	244000	323000
Positive responses to 'quality' questions in surveys (%)	99	98	98	99	98
Satisfaction of information requests as they occur (%)	⁹⁸	Sample too small	98	99	98

^{*} Affected by a long-duration equipment malfunction.

Management implications

The sustained level of information service provision, together with sound customer satisfaction evaluations, indicates that there is continuing strong demand for these services from the Observatory.

Future directions (next 12 to 18 months)

- Continue with the catalogue of historical items at the observatory and make this information available on the web.
- Continue to catalogue the books in the Perth Observatory's library.

- Continue to improve the astronomical web services, especially with social media.

Monitoring gravitational microlenses

SPP 1998-013

Team members

A Williams, R Martin, A Verveer

Context

Gravitational microlensing happens when the motion of the Sun and other stars around the Milky Way brings two distant stars into precise alignment. Rather than 'blocking out' the more distant star, the gravity of the nearer star instead bends light that would normally have missed the Earth inwards, amplifying the light from the distant star like a giant, natural telescope. As the two stars move into alignment, and then out again, what looks like one faint star in an image from the telescope gets brighter then dimmer again, over hours, days or weeks. Following the precise change in brightness over time allows many properties of the nearer (lensing) and further (lensed) stars to be determined. More importantly, if one or more planets is orbiting the lensing star, it can be detected relatively easily.

Microlensing observations must be carried out at frequent intervals, 24 hours a day, seven days a week, to cover the entire 'light curve' of the lensing process. This requires international collaboration, and the use of telescopes spaced out around the world, so that there is always at least one telescope observing at any given time. Perth data is combined with observations from collaborators using telescopes in Siding Springs (NSW), Tasmania, South Africa, the Canary Islands, Chile, Brazil and Hawaii (ranging from 0.6 m to 2 m) allowing 24-hour monitoring during the 'galactic bulge season' (May–August).

Aims

- Use precise light curve measurements in order to characterise the statistics and kinematics of Galactic microlensing events.
- Detect extra-solar planets.
- Gather information on the stellar population in and around the Galactic Bulge.

Summary of progress and main findings

- Four circulars published in 2012.
- Seven publications as a contributor to the PLANET project.

Management implications

Gravitational microlensing has developed into a powerful tool for studying stars and planets.

Future directions (next 12 to 18 months)

Perth Observatory involvement in this project is completed.

Imaging and CCD photometry of transient and variable sources

SPP 1998-011

Team members

A Williams, R Martin, A Verveer, G Lowe

Context

Transients are objects in the sky that suddenly appear, or existing ones that change without warning. Determining what they actually *are* requires 'follow-up' observations—monitoring their brightness over time, often using a wide range of wavelengths, from radio telescopes through to optical telescopes. Perth Observatory staff do follow-up observations on transient sources discovered by various telescopes around the world.

The Murchison Widefield Array (MWA) is a low frequency (80–300MHz) radio telescope being built at the proposed 'Square Kilometre Array' site in Western Australia. When operating, the MWA will generate a complete, high-resolution image of the entire sky, horizon to horizon, every eight seconds, in the selected radio frequencies. The MWA is one of three official 'precursor' telescopes for the Square Kilometre Array radio telescope (the other two are ASKAP in Western Australia, and 'MeerKAT' in South Africa), and the only one operating at low frequencies. It is expected to find vast numbers of transient sources at these frequencies, including types of object that have never been seen before. Development of software and electronics for the MWA is being undertaken through the International Centre for Radio Astronomy Research (ICRAR).

Aims

- Image newly discovered celestial objects and/or poorly known variable sources, so as to increase knowledge of astronomical objects, and discover new astronomical objects.
- Increase knowledge of the structure and processes within stars.

Summary of progress and main findings

- Construction of the full 128-tile array for the prototype telescope was completed.
- Four papers published from the MWA project.

Management implications

Involvement in the MWA will give Perth Observatory access to alerts for rapid follow-up observations when the MWA becomes fully operational.

Future directions (next 12 to 18 months)

Perth Observatory involvement in the project is completed.

STUDENT PROJECTS

The following reports were provided.

The compositional, structural, and functional succession of beetle communities in habitat mosaics created by three different fire regimes in the southern forests of Western Australia

Scientist

I Abbott

Student

P Van Heurck

Progress report

In March 2003 an intense wildfire in heavy fuels burnt approximately 20,000 ha of proposed national park north-east of Mt Frankland. The rapid southward spread of this wildfire was eventually controlled along the northern boundary of London forest block, which had been prescribed burnt in the previous spring. The contrasting intensities at which these adjoining two forest blocks were burnt have provided an opportunity to compare the impacts of fire on the biodiversity of their invertebrate communities. The aim is to compare the impact on beetle biodiversity of a patchy 'small-grained mosaic' fire regime, with that of a 'normal prescribed' fire regime and a 'no planned' regime, all in the adjoining forest blocks.

Fieldwork has been completed and to date 1100 samples containing 23,100 invertebrates have been sorted. 445 beetle morphospecies have been identified, of which 220 are rare and possible short-range endemics. As at 2012, one-third of these morphospecies were only collected from the patchy mosaic fire regime and another third of these morphospecies only collected from the wildfire regime. A prodromus listing each species' fire niche and life history attributes has been prepared. These results suggest that most of the beetle assemblage have narrow fire-niches.

Baiting effectiveness for introduced rats (*Rattus* sp.) on Christmas Island

Scientist

D Algar

Student

A Coddou

Progress report

The importance of oceanic islands for conservation of native species is often affected by the introduction of invasive species. Introduced mammalian predators such as feral cats (*Felis catus*) and rats (*Rattus* sp.) have been responsible for population decline and extinction of many native species on oceanic islands worldwide. Christmas Island, located in the Indian Ocean, is an example of how introduced mammals have influenced the population of endemic species even to the point of extinction.

The aim of this study was to monitor the effect of a baiting program for rats within the residential area, as part of the management plan for feral cats and rats conducted on the island since 2010. Twenty rats (ten in each site) were trapped in two study areas within town sites (*Settlement* and *Upper Poon Saan*). Rats were radio-collared and released, and then bait stations were opened containing Racumin paste sprayed with coconut milk as an additive. The baiting had a mean efficacy of 76.5%, with a significant difference ($\chi^2 = 4.650$, 1 df, $P = 0.031$) observed between the sites (100% at *Settlement* area and 55.5% at *Upper Poon Saan*). The mean time of action for the baits for both sites was 5.6 ± 0.6 days and the total mean bait consumption per bait station was 41.6 ± 9.07 g over 10 days. The results of this study suggest that the type of bait currently in use is adequate, but the spacing of baits may not be sufficient to successfully control rats on Christmas Island, particularly in the residential area. It is recommended that the non-baited stations are located prior to the baiting campaign so the structure

looks familiar to rats in order to avoid bait shyness. It is also recommended that the rubbish in the residential area is removed to reduce the habitat for rats, which will aid the control program.

Development of Curiosity feral cat bait

Scientist

D Algar

Student

M Johnston

Progress report

This PhD project is assessing the efficacy and utility of the Curiosity cat bait. This bait sausage contains a Hard Shell Delivery Vehicle (HSDV) that encapsulates the toxin para-aminopropiophenone that triggers toxicoses in cats, leading to death. The HSDV increases the specificity of the bait medium by exploiting differences in the mechanical digestion of food by some vertebrates. Many potential non-target species are known to reject large inert particles in their diet; however, the cat is more likely to ingest such particles by virtue of its characteristic form of mastication which selects large portions of food for swallowing, without grinding and sorting of small inert particulates. Bait efficacy trials in the Pilbara indicated a low bait uptake by cats. Non-target risk trials are continuing with particular emphasis on the northern quoll. Several reports have been published and are available on the Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment (Victoria) website.

Dietary study of feral cats (*Felis catus*) and black rats (*Rattus rattus*) to determine predatory impact and identify bait preference for use in a rat eradication program

Scientist

D Algar

Student

G Hayes

Progress report

Christmas Island is home to a unique and diverse fauna, which may be threatened by populations of introduced feral cats (*Felis catus*) and black rats (*Rattus rattus*). A four-year eradication program to remove cats and rats from the island commenced in 2010. As part of the eradication program, this study examined the diet of feral cats and black rats to determine the direct predatory impact on native species.

It was hypothesised that feral cats would primarily consume black rats and native vertebrate species, while black rats would supplement their diet of plant species with native vertebrate and invertebrate species. Additionally, a bait trial was conducted to determine the bait preference of black rats on the island. It was hypothesised that a coconut additive would improve the palatability of Racumin bait. The gut contents of feral cats and black rats, euthanised as part of an eradication program, were analysed. At the same time, a bait trial was conducted using three forms of Racumin bait. Examination of the guts of 33 feral cats showed the most frequently occurring food items were plants (72.7%) and invertebrates (63.6%), and the most abundant were plants ($13.7 \pm 3.5\%$), birds ($12.4 \pm 4.3\%$) and invertebrates ($11.1 \pm 2.9\%$). The gut contents of 51 black rats were examined, and plant material was the most frequently occurring (58.8%) and abundant ($20.8 \pm 7.8\%$) food item. Racumin paste soaked in coconut milk was identified as the most palatable bait for black rats.

Black rats in paradise: abundance and home range size on Christmas Island

Scientist

D Algar

Student

Low Bing Wen

Progress report

Understanding the spatial ecology of invasive rats (*Rattus* sp.) is necessary to inform management actions. This study investigated densities and home-range size of exotic rats around seabird colonies and urban areas on Christmas Island, where rat predation is suspected to be adversely affecting fledgling success among local seabirds. It was hypothesised that rat home-range sizes would be smaller in urban areas owing to more consistent food availability.

Both the core and foraging home ranges of male rats were significantly larger compared to their female counterparts, with male rats maintaining larger home ranges in urban areas compared with seabird colonies. Our findings suggest a possible correlation between the spatial distribution of food resources and home-range size. Additionally, the spatial distribution of breeding females across the landscape had a significant influence on the home ranges of male rats. These findings have significant implications for proposed efforts to manage rat populations on Christmas Island, while also providing valuable information regarding the ecology of invasive rats on tropical islands.

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

Investigation into the occurrence of parasites and the diet of feral cats and rodents will provide information to assist management. Necropsies have been conducted on cats from Christmas Island (n=67), Dirk Hartog Island (n=12) and south-west Western Australia (n=70). Necropsies involve searching all internal organs thoroughly for any endoparasites, as well as collection of tissue samples from these organs for later analysis. Blood and serum samples were taken from as many cats as possible. The gastro-intestinal (GI) tract was kept for later diet and parasite analysis. The stomach, small and large intestines were methodically searched under a dissecting microscope for any GI helminths. The stomachs were opened and examined for ingesta. Dietary material was also recovered from the small and large intestine.

To date 66 cats and 101 rats collected from Christmas Island have been necropsied and samples for further testing have been collected. More than 85% of both cats and rats were found to be harbouring at least one parasitic species, with both cats and rats found to harbour as many as seven different parasite species. Those species identified include a number of zoonotic parasites. Hookworms (*Ancylostoma* spp.) occur in cats at a high prevalence (85%); however none have been found in rats. The rat lungworm *Angiostrongylus*, a zoonotic parasite, was detected in ten rats. *Rodentolepis nana*, the zoonotic rodent tapeworm was also detected in two rats from Christmas Island, whilst adult stages of the Acanthocephalan parasite *Moniliformis moniliformis* have been found in both cats and rats. Molecular screening has commenced and preliminary results indicate a high prevalence (80%) of *Bartonella* spp. in rats. Screening for *Trypanosoma* spp. and *Leishmania* spp. has been negative for cats and rats. Recent confirmation of a case of leptospirosis in a fly in/fly out worker on Christmas Island has identified the bacteria *Leptospira* as a species of interest for future screening of both cats and rats.

Genetic diversity and phylogeography of Australian cats

Scientist

D Algar

Student

K Koch

Progress report

The origin of Australian cats was assessed by using samples from various mainland and island locations and samples from possible source populations (Asia, Europe). In addition, we determined the genetic variation, population structure and phylogeography of Australian cats to give insight into the colonisation processes and to assist future eradication plans.

Results indicated a European origin of Australian feral cats, with low indication for significant numbers of introduced cats from Malaysian trepangers. However, various islands show clear connections to cats from Southeast Asia and Australian Indian Ocean Territories. Analysis of DNA material from cats on Dirk Hartog Island and the adjacent mainland showed several main introduction events and reproductive isolation for the last few years. A sufficient large-scale eradication measure will therefore be successful in the long-term.

The value of remnant and revegetated woodland on Rottnest Island to the red-capped robin (*Petroica goodenovii*) and golden whistler (*Pachycephala pectoralis*)

Scientist

A Burbidge

Student

C Polson-Brown

Progress report

This study examined habitat use in two woodland passerines (red-capped robin and golden whistler) on Rottnest Island, to determine the value of remnant and revegetated sites and hence inform future woodland restoration efforts for birds. These two bird species declined in abundance on Rottnest following fragmentation of woodland habitat.

Red-capped robin abundance was greater in areas with taller trees and lower values for shrub layer cover, while golden whistler abundance was related positively to patch cover (i.e. a landscape variable). Total bird abundance was greater in areas with more shallow litter depths and lower patch cover. Robins spent equal amounts of time in open, edge and wooded areas, whereas whistlers spent about 75% of their time in woodland areas.

Robins occur in patches with older trees, fewer shrubs, and with open/edge areas in which to forage. Golden whistlers prefer more extensive, continuous woodlands. Current revegetation could be subjected to silvicultural treatment to provide a mix of such areas in order to optimise habitat for both species. Any future revegetation aiming to provide whistler habitat should focus on extending the area of current patches, whereas robins will benefit from patchy plantings of taller trees.

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; 500 km north-east of Perth) are biodiversity hotspots that harbour many SREs. This project will examine the genetic diversity and structure present in four, 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.

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 southwest. 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.

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 obtain insights into the main factors that affect natural recruitment success amongst species, seedling growth and mortality has been monitored at three burnt sites in the South Coast Region for a range of *Acacia* and *Banksia* species over the 2011/2012 summer. The aim of this experiment was to determine whether there are 'safe' sites for recruitment and what specific environmental factor(s) are associated with seedling survival and growth.

The experimental translocation of the Critically Endangered *Banksia ionthocarpa* ssp. *ionthocarpa* demonstrated survival of seedlings after two years is 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 the three different microhabitats that plots were placed in (bare, removed low heath, removed tall heath), seedlings had higher survival and grew most in the low heath plots. The experimental translocation of the Critically Endangered *Acacia awestoniana* showed that survival of seedlings after two years is very high at 81%, with treatments (watering, microhabitat, seedling age at transplant, soil-medium pretreatment) not showing significant differences with respect to survival, although there were substantial differences in terms of growth. Plants that were watered weekly (automatic) or monthly (manual) during summer showed enhanced growth when compared to non-watered plants. Faster growth during summer was associated with higher leaf temperatures as determined by infrared technology. Although this technique is promising in terms of non-invasively assessing plant drought stress, the variation amongst plants was relatively large.

Monitoring coral size-frequency distribution, an investigation into digital methods

Scientist

S Field

Student

J Turner

Progress report

This study aims to assess the effectiveness of using a stereo-video system to accurately quantify size distribution for a range of coral genera and morphologies over multiple habitat types of varying complexity. The study will compare the size-frequency distributions obtained by each of the three methods: *in situ*, stereo-diver operated video, and still images.

Fieldwork was completed in May 2012 as part of the Gorgon dredge monitoring program at the Montebello and Barrow Islands at a subset of the dredge monitoring sites. Subsequent analysis of the digital imagery has also been completed and the data are being analysed.

Finding a dietary surrogate for the Critically Endangered Gilbert's potoroo *Potorous gilbertii*

Scientist

T Friend

Student

J Pridham

Progress report

One of the primary strategies to promote the conservation of the potoroo is to establish translocated colonies. A requirement for the potoroo's habitat is significant hypogeal fungi, which constitutes 90% of its diet. Mycophagy is a trait shared with three more common mammals also found in the potoroo's habitat: bush rat (*Rattus fuscipes*), quokka (*Setonix brachyurus*) and quenda (*Isoodon obesulus*). Scats from live-captured animals at three sites will be microscopically examined to ascertain which has the most similar fungal diet to the potoroo, and to determine if one (or more) of the more common species can be used as an indicator of food resource abundance for Gilbert's potoroo to assess future translocation sites.

Sites have been selected from two areas where all four species occur: Mt Gardner (Two Peoples Bay Nature Reserve) where potoroos naturally occur and the Norman's Beach enclosure (Waychinicup National Park) where potoroos were translocated in 2010; and a Water Corporation reserve joining Two Peoples Bay Nature Reserve where bush rat, quokka and quenda occur. Samples have been obtained from all sites with trapping continuing in 2013 to obtain further scats for analysis.

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

Scientist

C Gosper

Student

B Lake

Progress report

This project assesses changes in biological soil crust cover and function (as changes in nutrient dynamics) of gimlet (*Eucalyptus salubris*) woodlands with increasing time since fire. Biological soil crusts are complex communities of soil inhabited by bacteria, cyanobacteria, algae, fungi, lichen and bryophytes, and are important components of arid ecosystems all over the world. Crusting organisms increase soil aggregation, reduce erosion, affect germination, influence vegetation patterns and affect the nutrient cycling dynamics of those soils that they occur in. 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.

Time-since-fire range and sites to be sampled have been identified. Field sampling (measuring crust cover, collecting representative samples for taxonomic identification, and soil samples for assessing crust function) has commenced. Laboratory analyses of soil samples have commenced.

The role of *Kyphosus* spp. in reef ecosystems

Scientist

A Kendrick, S Wilson

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 will be carried out in the Marmion, Shoalwater Islands and Ningaloo marine parks. A pilot study on how to best survey *Kyphosids* has been completed; some fish have been collected and analysed to assess diet. Data has also been collected on the abundance of *Kyphosids* at different depths and levels of reef relief.

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 broad aim of this study is 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*. To achieve this, the study will determine 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. Fieldwork has commenced in the Marmion and Shoalwater Islands marine parks.

P. mccullochi was found to be a strict herbivore, feeding almost entirely on foliose and filamentous red algae. The diets of juvenile and adult fish did not differ. Electivity indices indicated that *P. mccullochi* specifically selected *Brongniartella* sp., *Dasyclonium* sp., *Hypnea* spp. and *Dictyopteris* spp. Macroalgae assemblages differed significantly inside and outside *P. mccullochi* territories and a caging experiment in territories indicated a moderate effect on the composition of recruiting algae. Algal assemblages inside the territories were characterised by *Hypnea* spp. and *Dasyclonium* spp., while those outside the territories were characterised by *Ecklonia radiata* and *Sargassum* spp., *Rhodimonia sonderi* and *Amphiroa anceps*. This study has found that *P. mccullochi* may act as an ecosystem engineer by structuring algal communities on temperate reefs and maintaining high biodiversity patches within kelp canopies.

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 examples of 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*. Factors identified as contributing to fire behaviour included low-level sea breeze convergence, potential atmospheric instability, entrainment of

dry air from aloft, and vertical circulation associated with a frontal change. 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. Papers were presented to the Bushfire CRC research forum in Perth in August 2012, and at a national fire weather workshop in Busselton in May 2013.

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

Burrowing bettongs (*Bettongia lesueur*) are listed as near threatened by the International Union for Conservation of Nature (IUCN). The remaining populations can only be founded on the Shark Bay islands and Barrow Island. These remnant populations have been recognised as different subspecies, with *B. l. lesueur* from Bernier and Dorre Islands in Shark Bay, and an undescribed subspecies from Barrow Island. Animals of the same subspecies from these populations have been translocated to several sites. Lorna Glen is the first site that aims to promote a mixing at the subspecies level. This study aimed to monitor the genetic consequences of translocating burrowing bettongs, especially to test whether there was genetic mixing between bettongs originating from the Barrow Island population and the Dryandra Field Breeding Facility (established from Dorre Island bettongs), and the outcomes on the offsprings' morphology.

DNA analysis used 18 microsatellite loci and mitochondrial DNA from the D-loop region to examine the genetic variation in founder and founder-offspring populations. Preliminary results confirmed that there is a substantial differentiation between Shark Bay and Barrow Island populations. The genetics of F1 and F2 animals showed there was random mixing between founders from different source populations with no apparent sign of outbreeding depression. The translocated population had a higher genetic diversity of both mtDNA and nDNA than its parental populations. However, mtDNA results up until 2013 suggested that Dryandra females contributed to the translocated population more than Barrow Island females. The purebred offspring, on average, were slightly smaller than their parental populations, while crossed-mating offspring had a large body size similar to Dryandra purebreds. From this study, we recommend adding more females from Barrow Island to increase mitochondrial diversity at the Lorna Glen site, followed by genetic monitoring of offspring three to five years later.

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*.

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.

Progress has been made on a literature review, and relevant hydrological data were evaluated to guide research and activities. A monitoring system has been developed for surface and groundwater and aquatic invertebrates and waterbirds are being monitored when conditions are conducive.

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* have been identified and are being tested for suitability for population genetic studies of selected species. Amplification of COI and 16S regions of the mtDNA from selected species of *Parartemia* is being undertaken.

Multiple new *Phytophthora* species from Western Australia: taxonomy, pathogenicity and disease control

Scientist

M Stukely

Student

A Simamora

Progress report

The aim of this study is to identify *Phytophthora* isolates using DNA sequence data from rDNA internal transcribed spacer regions (ITS) and the mitochondrial *cox1* genes in association with morphological and physiological characteristics. In addition, pathogenicity tests and the disease control of selected isolates from all the new species described will be undertaken. The outcome of this study will be to increase the knowledge about the species of *Phytophthora* present in native plant communities in Western Australia, their pathogenicity and their potential control by phosphite.

A re-evaluation has been made for some *Phytophthora* isolates with similar morphological characters to *P. arenaria*, but with some variation in ITS region sequences, and which have been referred to as *P. aff. arenaria* type I (with the vast majority of isolates coming from nurseries and urban tree plantings, and predominantly from *Eucalyptus*) and type II (predominantly from natural vegetation on the northern sandplains). A re-evaluation of these species using morphological, physiological and molecular characteristics using a combination of four gene regions, *cox1*, HSP90, enolase and BT, suggests that type I isolates are *P. alticola*, while type II isolates are *P. arenaria*. Thus the species that has been found in the nursery on *Eucalyptus* is *P. alticola*. Pathogenicity trials using *P. alticola*, *P. arenaria*, and *P. cinnamomi* isolates on one- and three-month-old *Eucalyptus* seedlings (*E. polybractea*, *E. kochii* ssp. *plenissima*, *E. kochii* ssp. *borealis*, *E. loxophleba* ssp. *lissophloia*, and two seedlots of *E. loxophleba* ssp. *gratiae*) in the glasshouse indicated that *P. alticola* can infect all *Eucalyptus* seedlings whilst *P. arenaria* had little effect. *Phytophthora cinnamomi* infected *E. kochii* ssp. *plenissima*, *E. kochii* ssp. *borealis* and *E. loxophleba* ssp. *lissophloia*.

Regional variability in salmon gum communities in the Great Western Woodlands

Scientist

S van Leeuwen

Student

J Harvey

Progress report

This project aims to determine if there is regional variation in the understorey of *Eucalyptus salmonophloia* woodlands across the Great Western Woodlands (GWW) and, if so, what is driving it. It will integrate relevant existing survey data from across the Wheatbelt to assess the variation across the two bioregions. This project fills large gaps in the floristic surveys of the GWW, which have focused on the banded ironstone and greenstone ranges. One hundred sites have been sampled in Spring 2011 and 2012, in old growth woodlands or woodlands where the known timber cutting and or grazing history has been 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 groups and four small groups that corresponding with geographical outliers and grazed sites. The two main groups consist of one to the north and east of the GWW with an understorey of mainly chenopod species, and the other to the south and west with non-chenopod species (*Eremophila* spp., *Acacia* spp., *Scaevola spinescens* and *Alyxia buxifolia*). Comparisons with the Wheatbelt and investigations into methods to model the distribution of salmon gum communities are still underway. This project will contribute to knowledge about these woodlands relevant to land management decisions regarding fire, timber harvesting and pastoral activities.

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 trypanosome blood parasites on human and livestock health, trypanosomes in wildlife, although ubiquitous, have largely been considered to be non-pathogenic. This project aims 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 Australian marsupial, the brush-tailed bettong or woylie (*Bettongia penicillata*).

554 blood samples and 250 tissue samples collected from 50 carcasses of sick-euthanized 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. This marsupial showed high rates of infection with *T. copemani* (96%) in the declining population, whereas in the stable population, *T. 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 *T. copemani* showed pathological changes similar to those seen in *Didelphis marsupialis* infected with the pathogenic *T. 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 colonize different tissues in the host but also to invade cells *in vitro*. These results provide evidence for the potential role of trypanosomes in the decline of a formerly abundant marsupial that is now critically endangered, 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 and a paper has been published in the *International Journal for Parasitology: Parasites and Wildlife*.

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 progress.

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 contributes to investigations aiming to determine if disease is a significant factor in the recent woylie (*Bettongia penicillata*) declines and lack of recovery. The project is unique in that it compares health and disease over time in three different population management systems: a wild population in the Upper Warren; an insurance population at Perup Sanctuary; and a captive insurance population previously at Perth Zoo. Studying the sanctuary (free-range predator-proof enclosure) population allows the investigation to focus on the role of disease in the absence of introduced predators.

Health testing includes haematology, biochemistry, gastrointestinal parasites, anti-oxidant and vitamin levels, and determination of stress levels using hair, faecal and serum cortisol. The project has validated the use of faecal glucocorticoids as a measure of stress for this species, and plans to also validate the use of hair. Screening for significant marsupial pathogens includes haemoparasites, toxoplasmosis and selected viruses including herpes virus and Warrego and Wallal orbiviruses. Complete testing of samples and analyses are pending. The increase in understanding of woylie health, stress and disease this project brings will aid in the recovery and management of this critically endangered species.

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 aims to assist the extensive conservation effort involving government agencies, zoos and universities regarding the alarming reduction in woylie numbers, with a focused investigation into the correlation of the trypanosomes found in the blood of the woylies and the overall population decline of the host. As part of a parasitological study to understand this dramatic decline, it was discovered that the trypanosomes in the blood of woylies were grouped into three morphologically distinct trypomastigote forms, encompassing two separate species. The larger of the two species, *Trypanosoma copemani*, exhibited polymorphic trypomastigote forms, with morphological phenotypes being distinguishable, primarily by the distance between the kinetoplast and nucleus. The second trypanosome species was only 20% of the length of *T. copemani* and is believed to be one of the smallest recorded trypanosome species from mammals. No morphological polymorphism was identified for this genetically diverse second species.

We described the trypomastigote morphology of this new, smaller species from the peripheral blood of the woylie and proposed the name *T. vegrandis* sp. nov. Temporal results indicated that during *T. copemani* Phenotype 1 infections, the blood forms remain numerous and are continuously detectable by molecular methodology. In contrast, the trypomastigote forms of *T. copemani* Phenotype 2 appear to decrease in prevalence in the blood to below molecular-detectable levels.

In this study, we have reported for the first time on the morphological diversity of trypanosomes infecting the woylie and provide the first visual evidence of a mixed infection of both *T. vegrandis* sp. nov and *T. copemani*. We also provide supporting evidence that, over time, the intracellular *T. copemani* Phenotype 2 may become localised in the tissues of woylies as the infection progresses from the active acute to chronic phase. As evidence grows, further research will be necessary to investigate whether the morphologically diverse trypanosomes of woylies have impacted on the health of their hosts during recent population declines.

Wildlife ecology in the southern jarrah forest

Scientist

A Wayne

Student

G Yeatman

Progress report

This project will investigate ecological attributes of woylie and other small mammals in the jarrah forest. Specifically it 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) calculate an estimate of woylie (*Bettongia penicillata*) home-range size in and outside the newly constructed Perup Sanctuary; iv) investigate spatial patterns in the current distribution of woylies across the Upper Warren Region in relation to habitat variables; and v) investigate temporal patterns in the distribution of woylies across the Upper Warren Region over the past three decades.

Progress to date includes the completion of radio tracking and collection of data for woylie home-range analysis; completion of baseline surveys of small vertebrates in and outside Perup Sanctuary and across habitat types; and completion of habitat surveys of Upper Warren regional monitoring trapping points for woylies. A report has also 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.

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 project is to increase our understanding of the role of *Toxoplasma gondii* in wild woylie populations, particularly with regard to the population decline of this species. *Toxoplasma* can infect virtually any warm-blooded vertebrate, and has a worldwide distribution. In asymptomatic laboratory and wild rodents, *Toxoplasma* causes subtle changes in behaviour that are thought to make infected hosts more susceptible to predation. If *Toxoplasma* has a similar effect on 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 DEC staff over the past six years will be analysed to determine *Toxoplasma* infection status. This will provide insights into the ecology of *Toxoplasma* infection in woylie populations and an opportunity to investigate whether *Toxoplasma* alters woylie behaviour by correlating infection status with behavioural attributes. An increased understanding of the role of this parasite in woylie populations will aid in the management of this threatened species.

Trapping data is being prepared to investigate behavioural traits in the sampled woylies and whether behavioural groups exist in the woylie population. For example, are there groups of woylies that are 'less afraid' (more likely to go into a trap, less stressed about human handling, etc.) compared with woylies that are 'more afraid' (less inclined to approach a trap, more agitated on human handling, more likely to have pouch young complications)? If so, we will overlay the infection status of these woylies to see whether a particular behavioural type correlates with *Toxoplasma* infection.

***Toxoplasma gondii* infection and atypical genotypes in Western Australian wildlife species**

Scientist

A Wayne

Student

S Pan

Progress report

In total, 415 samples (342 marsupials and 73 introduced animals) and 171 individuals (132 marsupials and 39 introduced animals) were screened for *T. gondii*. Nested-PCR markers specific for gene locus *B1*, *SAG1*, *SAG2*, *SAG3*, *SAG4*, *GRA6* and *GRA7* have been carried out for all samples. Extensive optimisations were carried out to select the right gene markers suitable for Western Australian wild animal samples and reproducible results were obtained. This study has accumulated over 330 DNA sequences across multiple animal species and gene markers.

In total, 60% (256 out of 415) tissue samples and 76% (130 out of 171) individual animals were infected with *T. gondii*. The marsupial samples were detected with a typical infection rate of 75% (100 out of 132). Out of the total 30 Western Australian native animal species, including 14 out of 16 marsupial and 12 out of 14 native and introduced animals, in total 26 animal species were infected with *T. gondii* (87%). This study found 23 of 28 (82%) woylies, 18 of 22 (82%) chuditch, 6 of 11 (54%) brush-tail phascogales, and 8 of 18 (50%) ring-tail possums were infected with *T. gondii*. Results show very high variation, and unique *T. gondii* genotypes in multiple loci have been revealed in a range of animal species such as kangaroos, chuditch and woylie. This research has been presented at three international conferences and a paper published in PLOS One in 2012.

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 has been sampled and in most cases identified to species level using existing keys. A literature review has been 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 brush-tail possum (*Trichosurus vulpecula*). Data are currently being prepared for publication.

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.

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 quokkas in southern forests; iii) identify the current distribution and abundance of quokkas in the southern forests (Warren Region) and the influence of fire; iv) determine the mobility and activity patterns of quokkas in the broader landscape; and v) in collaboration with others determine whether the sub-populations constitute a functional meta-population.

All field work is now complete; a survey method based on counts of fresh faecal pellet groups was found to provide a reliable and practical estimation of population abundance. Stepwise logistic regression models of habitat surveyed for presence/absence of quokka 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. Between March 2010 and March 2013, fire-treated sites and comparable control sites were 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 recolonised post-fire. Radio collars fitted to 17 animals in a recently burnt jarrah forest ecosystem and 10 animals in a longer-unburnt jarrah forest ecosystem were monitored between January 2011 and April 2013, to determine movement patterns and habitat use. Quokka DNA was provided to Peter Spencer at Murdoch University, to determine the genetic importance of the southern forest quokkas and whether sub-populations constitute a functional meta-population.

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.

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. A useful state-space model that is applicable to other Argos datasets from large marine animals was developed. This information will be formalised in four scientific papers and has been communicated back to the local community via several types of media. In addition, this project developed a cooperative working relationship with the Anindilykwa Aboriginal Land Council at Groote Eylandt and developed a community census program for ongoing monitoring.

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 conservation and management 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, this project will investigate the abundance and biomass of several species of meso-predatory fish at Ningaloo Reef, develop an enhanced understanding of the group's functional role, and identify the trophic position of meso-predators in coral reef food webs using direct diet analysis, age determination and abundance estimates. Processing of otoliths to assess age and mortality rates of several meso-predator species has commenced and estimates of abundances of meso-predatory fish using underwater visual census are being determined.

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 has started with collection of data to assess which survey techniques best detect impacts of harvesting. Data from two other tabu areas has also been collected and will be used to assess impacts of harvesting.

Quantitative diet analysis of four meso-predators 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. Meso-predators are common on coral reefs and fluctuations in their abundance may influence prevalence of prey; however, there is a lack of information on meso-predator 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 meso-predator 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 submitted to *Journal of Fish Biology* and is currently in review.

Climate change impacts on the northern sandplain kwongan vegetation of south-western Australia

Scientist

C Yates

Student

A Williams

Progress report

Experimental studies investigating the relationship between climate and demography are needed to better understand the vulnerability to species to climate change. This research aims to quantify plant demographic behaviour (survivorship, growth and fecundity) under projected climate change using experiments that manipulate rainfall and temperature. The research is being undertaken in the diverse kwongan heath vegetation on the Eneabba Sandplain, a nationally recognised hotspot, which is projected to become warmer and drier.

Rain-out shelters and irrigation of diverted rainfall, were used to reduce and increase ambient rainfall by ~30%. Surface soil moisture was significantly drier (by 15 %) and wetter (by 13 %) than controls for rain-off and rain-on plots respectively. Open top chambers were used to increase temperature, which resulted in a mean daily increase of 1.7 °C and a mean maximum of 5.5°C. Response of mature vegetation vs. regenerating vegetation (post fire) was examined, as well as plant response across a topographic gradient (deep sanded dunes vs. shallow sanded swales), resulting in four sites each with a unique combination of fire history and topography. Plant demographic parameters were measured to assess vegetation response, using plant functional type (PFT) to group species response. PFTs of interest were fire response (resprouters vs. non-resprouters), growth form (shrub vs. subshrub), leaf type (broad, needle, small) and seed size (large, medium, small).

Reduced rainfall significantly lowered germination, survival and shoot biomass of seedlings, survival of adults, and flower and fruit production. Declines in canopy health and growth were also observed but these trends were not significant. Functional traits with highest resilience at the seedling stage were nonsprouters, small leaves and small seeds, while small leaved subshrubs had highest resistance as adults, but surprisingly mature resprouters did not have higher resistance than nonsprouters under drier conditions. Also surprising was the lowered resistance of resprouting vegetation following fire. Increased rainfall did not have as strong an effect as decreased rainfall with mixed directions of response across demographic parameters, e.g. lower seedling survival and biomass, but higher germination at the seedling stage, and increased survival and health, but lowered reproductive output in mature vegetation. Mature resprouters were best able to utilise additional water, being the only functional trait to significantly increase survival in the rain addition treatment. Increased temperature significantly reduced germination and survival at the seedling stage, survival and growth of adults, and fruit production, through direct and indirect (drying) effects. Functional traits with highest resilience were nonsprouters, large seeds and needle leaves, while resistance of mature vegetation was highest for resprouters and needle leaved species.

The results from the study indicate that the projected warmer and drier conditions for SWWA will result in declines in species richness and changes in composition of kwongan towards lower stature drought tolerant species.

Population variation in seed and seedling traits along a climate gradient in south-west Western Australia

Scientist

C Yates

Student

A Cochrane

Progress report

Germination and early establishment are high risk phases in the life-cycle of obligate seeding plant species. This research aims to assess the extent of vulnerability to a changing climate in these phases and to determine the potential for phenotypic plasticity in seed and seedling traits across populations of four *Banksia* species along a rainfall gradient in south-western Australia.

A common garden was used to examine the between and within species variation in seedling emergence (timing and total), growth (aboveground biomass and its allocation,) and leaf traits (leaf size and number, specific leaf area and leaf production rate) under two levels of soil warming (ambient and 1° C higher) and three levels of precipitation (ambient, 80 % lower, 140 % higher). Species differed significantly in all measured traits but few traits varied significantly across treatments. Soil warming slowed seedling emergence for two species and reduced total seedling emergence in three. In addition, warming altered seedling performance with significant changes to leaf: stem biomass ratio in three species. There was little observed response to changes in soil moisture. Some traits expressed significant differences among populations, but little evidence that this variation was associated with climate of seed origin. The data indicate that warming may differentially affect seedling establishment of these shrubs across their geographic range, with mixed responses. A draft manuscript describing the common garden experiment has been prepared for submission to a scientific journal.

A laboratory experiment was used to investigate the potential impacts of reduced rainfall and increased moisture stress on seed germination in multiple populations of the four *Banksia* species. Seeds were incubated at a range of water limiting conditions (moisture potentials of 0 to -1.5ψ using polyethylene glycol solutions) and three constant temperatures (10, 15 and 20 °C) for eight weeks. Drought stress both reduced and delayed germination. There was a significant temperature by moisture interaction for all species. Under drought stress *Banksia media* was least vulnerable to germination failure; and *B. coccinea* was most vulnerable. The significant variability in tolerance to drought stress observed at the population level did not vary predictably with rainfall or mean temperature across species' distributions.

