

2014–2015

Annual Research Activity Report
and Management Implications

Science and Conservation Division

Department of Parks and Wildlife

Director's Message

The past year has presented many challenges for the Division as we sought to meet the expectations of government at a time of fiscal constraint. These challenges presented the opportunity to review our activities to focus on the core functions we are required to deliver to support government priorities. Our Strategic Plan identifies how our science is integrated into delivery of the Department's strategic goals of wildlife management, parks management, forest management, and managed use of natural assets.

In reviewing our business we articulated our core functions as conserving threatened plant, animals and communities, landscape scale conservation, wildlife assets and inventory, WA Herbarium, bushfire research, marine monitoring and research, forest monitoring and research, wetland monitoring, hydrological monitoring, and data management and distribution. We have aligned our resources with these functions and refocused our activities to ensure we are delivering best practice science driven by management priorities to inform effective wildlife conservation and parks management.

Through all of this we have continued to deliver significant scientific information to support conservation of our diverse plants, animals and ecological communities. Highlights of activities this year include publication of a book documenting the outcomes of the Kimberley Islands Biological Survey; documenting the response of mammals to the establishment of a patchy early dry season burning regime in the Kimberley; development of genetic monitoring techniques for bilbies; registration of the cat bait, *Eradicat*, for operational use after many years of research; significant reduction in cats on Dirk Hartog Island following baiting; production of a book on algae of the north-west waters; production of a fire spread model for coastal scrublands of the south-west; revision of the fire behaviour ratings for communities in the Great Western Woodlands; increased understanding of effects of climate change and adaptation in coral reef communities, widespread eucalypts and in seed germination; addition of the 10,000th plant species to the WA census and description of 35 new plant species; maintenance of genetic diversity in seed collections from populations now extinct due to impacts of *Phytophthora*; understanding of seed collection zones for south-west forest rehabilitation and land restoration in the mid-west; establishment of an innovative citizen science program to monitor little penguins and visitor access to Penguin Island.

A Science Statement for Western Australia was released in April and it is pleasing to see that Biodiversity and Marine Science is one of the five science priorities for Western Australia, along with mining and energy, medicine and health, agriculture and food, and radio astronomy. The Science Statement announced State Government support for establishment of the Western Australian Biodiversity Science Institute (WABSI), a joint venture between nine partners including Department of Parks and Wildlife, Botanic Gardens and Parks Authority, WA Museum, CSIRO, The University of Western Australia, Murdoch University, Curtin University, Department of Mines and Petroleum and Office of the Environmental Protection Authority. Several other partners have been members of the Steering Committee guiding the development of WABSI, including BHP Billiton, Rio Tinto, Fortescue Metals Group, and the Chamber of Minerals and Energy, under the leadership of Professor Alan Robson. WABSI will have a Governing Council and a Board to guide its operations, and with support for the governance and administrative operations from the State Government. It will be organised around four nodes of Information Management, Biodiversity Survey, Biodiversity Processes and Threats, and Restoration and Ex-situ conservation, with node leaders responsible for engaging all relevant partners in delivering the agreed research plan for each node. I look forward to engagement of the Division in all of the nodes as the institute develops.

Our partnership with Western Australian Marine Science Institution (WAMSI) continues with projects fully operational and starting to deliver outcomes. The WAMSI conference held in April highlighted the wide range of projects being delivered through the Dredging Science Node and the Kimberley Marine Research Program. The Blueprint for Marine Science was also released and implementation will be further developed through the Premier's Round Table process.

Another major development in the past year has been the funding of the National Environmental Science Program (NESP) and we have significant involvement in three hubs, the Threatened Species Hub, the Northern Australian Environment Hub and the Marine Science Hub. The NESP hubs are strongly aligned with our own objectives as they are seeking to deliver applied research to support on-ground management; hence we have a significant role to play in these hubs through our integrated and highly applied research function. I encourage

you all to be involved in the hubs where relevant.

In April, we hosted a visit by delegates from the Institute of Botany-Jiangsu Province and Chinese Academy of Sciences. This visit followed the signing of a Memorandum of Understanding between the WA Government and the Jiangsu Institute, aimed at the development of joint programs that build on shared interests and research strengths, including participation in an international exchange of seeds, plants and specimens. Similarly, we welcomed a visit by the Commonwealth's Threatened Species Commissioner to enhance collaborations and improve awareness of the opportunities for investment in threatened species research and management in WA.

We continue to maintain excellent partnerships with universities, CSIRO, industry, not-for-profit-organisations and other government agencies with many new projects and a large number of students that we co-supervise.

As we consolidate after some major change over the past two years, I am confident we will continue to deliver excellent science to underpin effective biodiversity conservation in Western Australia. I encourage you all to make the most of all opportunities and continue to seek innovative ways of delivering science to support conservation. Our engagement with the conservation function continues to deliver excellent outcomes as we integrate our science expertise with our conservation policy capacity, enabling our science to more directly inform conservation policy and management, and for management requirements and knowledge gaps to set our research priorities. Our engagement with regional staff and with staff from Forest and Ecosystem Management and Parks and Visitor Services Divisions is critical to implementation of effective science to support the department's core functions.

I look forward to continued engagement with all our partners, both within the Department and externally, in delivery of innovative science to inform conservation and management of our plants, animals and ecosystems, and to support effective management of our parks and reserves, delivery of our fire program, managed use of our natural resources and science stories that inspire and engage people to explore and appreciate our natural heritage.

Dr Margaret Byrne
Director Science and Conservation
August 2015

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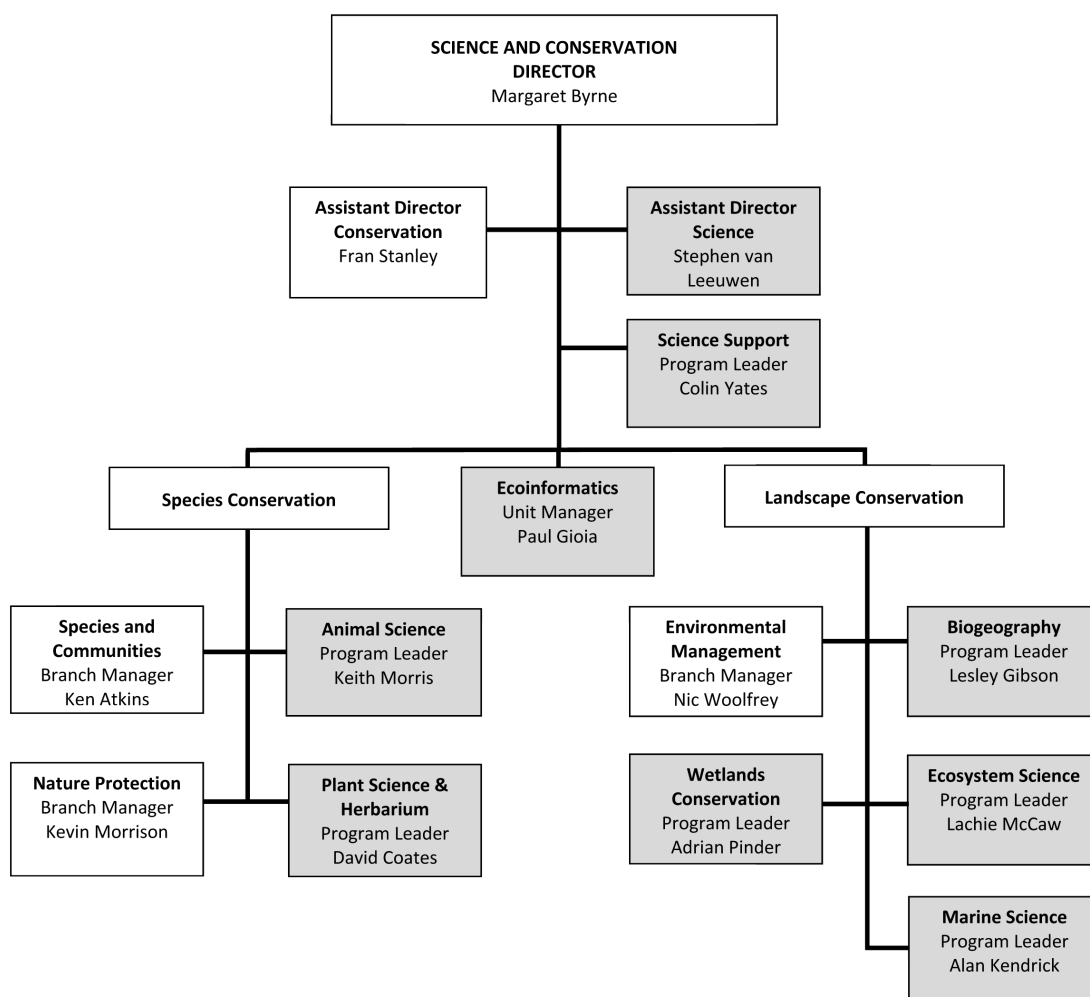
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Service Delivery Structure



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

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

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

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

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Current Collaboration with Academia (Student Projects)

DPaW Officer	Student	Academic	Project Title	Duration	Page
D Algar	N Dybing (PhD)	Dr P Adams	Parasites and diet of feral cats and rodents on mainland Western Australia and offshore Islands (Christmas Island and Dirk Hartog Island)	2012 – 2014	141
N Burrows	M Wysong (PhD)	Prof R Hobbs (University of Western Australia), Dr E Ritchie (Melbourne University)	The ecology and interactions of dingoes and feral cats in the arid Rangelands of Western Australia	2012 – 2015	142
R Butcher, K Thiele, M Byrne	E Joyce (BSc (Honours))	Prof P Grierson (The University of Western Australia)	Investigation of taxonomic boundaries in the <i>Tetratheca hirsuta</i> Lindl. complex	2013 – 2014	142
M Byrne	None (PhD)	None	Vegetation responses to Noongar land management practices in old and young landscapes	2014 – 2018	143
M Byrne, D Coates	H Nistelberger (PhD)	Dr D Roberts	Ancient, terrestrial islands in a semi-arid landscape: patterns of genetic diversity in regional endemics of the Yilgarn Banded Iron Formations	2010 – 2014	144
D Coates, K Thiele	L Craft (BSc (Honours))	Prof L Mucina (The University of Western Australia)	Assessment of hybrid status and conservation significance of intermediate populations within the <i>Stylidium caricifolium</i> complex (Stylidiaceae) in south-west Western Australia	2014 – 2015	144
D Coates	C Allen (PhD)	A/Prof P Poot, A/Prof M Moody (The University of Western Australia), A/Prof R Standish	Factors that affect seedling establishment and the implications for the translocation of species at risk of extinction	2010 – 2014	145
A Friend	J Austen (PhD)	Dr U Ryan	Trypanosomes of some Western Australian mammals: phylogenetics	2006 – 2012	145
J Huisman	R Dixon (PhD)	J Huisman	Systematics of <i>Sargassum</i> (Phaeophyceae) in Australia	2008 – 2012	146
G Keighery	T Hevroy (PhD)	A/Prof M Moody (The University of Western Australia), Dr S Krauss (Botanic Gardens and Parks Authority)	Molecular taxonomy, phylogeography and population genetics of the <i>Grevillea thelemanniana</i> complex	2010 – 2012	147

DPaW Officer	Student	Academic	Project Title	Duration	Page
A Kendrick	F Vitelli (PhD)	A/Prof G Hyndes	Feeding ecology of Pomacentridae and its ecological role in fish herbivory in temperate algal-dominated reefs	2012 – 2013	147
A Kendrick	A Turco (PhD)	A/Prof G Hyndes	The role of <i>Kyphosus</i> spp. in reef ecosystems	2012 – 2015	148
L McCaw	M Peace (PhD)	Dr T Mattner, Dr G Mills, Dr J Keppert	Fire weather	2010 – 2014	148
K Morris	J Dunlop (PhD)	Prof A Thompson (Murdoch University)	Factors affecting fauna translocation success	2010 – 2013	149
K Morris	K Bettink (PhD)	Dr H Mills	Ecology and taxonomic differentiation in the Australian water rat and implications for its conservation status in Western Australia	2010 – 2014	150
K Morris	R Thavornkanlapachai (PhD)	Dr H Mills	Genetic consequences of mammal translocations in Western Australia using case studies of dibblers, boodies and black-flanked rock wallabies	2011 – 2014	150
A Pinder	J Lizamore (PhD)	Dr R Vogwill (The University of Western Australia)	Nutrient movement and its impact on aquatic invertebrates as a food source of waterbirds between different wetland suites within the Lake Warden Wetland System	2013 –	151
K Thiele	B Anderson (PhD)		Diversity in the <i>Triodia basedowii</i> E.Pritz. species complex and its implications for the evolution of the Australian arid zone biota	2012 – 2016	152
K Thiele	(PhD)		Phylogeny, systematics and evolution of the Australian arid-zone <i>Ptilotus</i>	2015 – 2018	152
K Thiele	(PhD)		Are <i>Banksia</i> species changing in response to a drying climate? An investigation of potential range contraction and leaf indices of stress	2014 – 2015	153
S van Leeuwen	J Harvey (MSc)	Dr R Harris, Prof L Mucina (The University of Western Australia), Dr S Prober (CSIRO)	Regional variability in salmon gum communities in the Great Western Woodlands	2011 – 2013	153
A Wayne	K Bain (PhD)	A/Prof R Bencini	Ecological study of the quokka (<i>Setonix brachyurus</i>) in the southern forests of south-west Western Australia	2006 – 2014	154
A Wayne	G Yeatman (PhD)	Dr H Mills	Wildlife ecology in the southern jarrah forest	2011 – 2014	155
A Wayne	A Botero (PhD)	Prof A Thompson (Murdoch University)	Diversity of trypanosomes infecting Western Australian marsupials: virulence and pathogenicity	2010 – 2014	156

DPaW Officer	Student	Academic	Project Title	Duration	Page
A Wayne	K Skogvold (PhD)	Dr K Warren, Dr S Vitali, Dr C Holyoake, Dr C Monaghan	A comparative health and disease investigation in the woylie: captive vs free-range enclosure vs wild	2010 – 2014	156
A Wayne	M Pleitner (BSc (Honours))	Dr D Mahsberg	An exploration of the associations between the population decline of <i>Bettongia penicillata ogilbyi</i> (Gray, 1837) and field health assessment data from the Upper Warren region Western Australia	2014 – 2014	157
A Wayne	H Burmej (PhD)	Prof A Thompson (Murdoch University), Dr A Smith	Ectoparasites of threatened mammals in Western Australia: biodiversity and impact	2007 – 2014	157
A Wayne	A Atkinson (PhD)	Dr C Pacioni (Murdoch University), Dr P Spencer (Murdoch University)	Validating management options for maximising genetic “success” in translocation programs for the Woylie (<i>Bettongia penicillata ogilbyi</i>)	2014 – 2015	158
A Wayne	A Northover (PhD)	Prof A Thompson (Murdoch University)	Investigating the impact of polyparasitism in translocated woylies (<i>Bettongia penicillata</i>), and the effect of anti-parasite treatment on host fitness and survivability.	2014 – 2017	159
A Wayne	C Thompson (PhD)	Prof A Thompson (Murdoch University)	Trypanosome polyparasitism and the decline of the critically endangered Australian potoroid, the brush-tailed bettong (<i>Bettongia penicillata</i>)	2010 – 2014	159
A Wayne	S Hing (PhD)	Prof A Thompson (Murdoch University), Dr S Godfrey (Murdoch University)	Stress and disease in critically endangered woylies (<i>Bettongia penicillata</i>)	2014 – 2014	160
A Wayne	A Worth (PhD)	Prof A Thompson (Murdoch University), A/Prof A Lymbery, Dr T Fleming	The role of <i>Toxoplasma gondii</i> in declining populations of the woylie (<i>Bettongia penicillata ogilbyi</i>)	2011 – 2013	160
A Wayne	K Jones (PhD)	Prof A Thompson (Murdoch University), Dr S Godfrey (Murdoch University)	Pathogen transmission in the critically endangered woylie: a community, population, and individual approach	2014 – 2017	161
A Wayne	U Parkar (PhD)	Prof A Thompson (Murdoch University)	Genetic diversity of <i>Blas-tocystis isolates</i> found in West Australian native fauna	2013 – 2014	162
A Wayne	Z Lim (PhD)	Prof A Thompson (Murdoch University), Dr S Godfrey (Murdoch University)	Histopathological review of the causes of death in Woylies (<i>Bettongia penicillata</i>) presented to Murdoch University for necropsy in the last 10 years, with special focus on (possible) <i>Trypanosoma</i> related histopathology.	2014 – 2016	162

DPaW Officer	Student	Academic	Project Title	Duration	Page
S Whiting	N Robson (BSc (Honours))	Dr M Thums, Dr C Patiaratchi	Optimal release locations and timing for rehabilitated sea turtles using a decision support system	2014 –	163
S Whiting	J Stubbs (PhD)	Dr N Mitchell (University of Western Australia)	Assessing the resilience of marine turtle embryos to extreme temperatures	2011 –	163
S Whiting	B Bentley (BSc (Honours))	Dr N Mitchell (University of Western Australia), Dr J Kennington, Dr O Berry	Predicting the effect of climate change on embryonic flatback (<i>Natator depressus</i>) and green (<i>Chelonia mydas</i>) sea turtles in the Kimberley region of Western Australia	2014 – 2017	164
S Whiting	J Tedeschi (PhD)	Dr N Mitchell (University of Western Australia), Dr O Berry, Dr M Meekan	Assessing the resilience of marine turtle embryos to extreme temperatures	2011 –	164
S Wilson	J Goetze (PhD)	Dr T Langlois (University of Western Australia)	Variation in the intensity of periodic harvests in Fijian tabu areas and the effect on reef fish assemblages	2012 – 2015	165
S Wilson	I Lim (BSc (Honours))	Dr C Fulton	How does a seaweed-associated reef fish respond to seasonal habitat loss?	2014 –	165
S Wilson, G She-drawi	K Bennett (PhD)	Dr T Langlois (University of Western Australia)	Can diver operated stereo-video surveys of fish be used to collect meaningful data on tropical coral reef communities for long term monitoring?	2014 – 2015	166

External Partnerships

Partnership	Project Title	External Funding	DPaW Involvement
ARC Linkage, Murdoch University	The ecology of parasite transmission	\$150k over three years	K Morris, A Wayne
Department of Fisheries (Dr Mike Travers, Dr Steven Newman), CSIRO (Dr Oliver Berry), AIMS (Dr Mark Meekan), Curtin University (Joey Di Battista)	Connectivity of coral trout populations between individual reefs on the Rowley Shoals	DPaW 0.05 FTE in 2015 and 0.05FTE in 2016	AR Halford
ARC Linkage, Australian National University, CSIRO, Alcoa	Genomics for climate adaptation in <i>Eucalyptus</i> foundation species	\$375K for 2013-2016	M Byrne
WAMSI Kimberley Node 1.2.2	WAMSI Project 1.2.2. Key biological indices required to understand and manage nesting sea turtles along the Kimberley coast	\$1200K	S Whiting, T Tucker
State NRM	Fast track critically endangered flora recovery	\$1.6M (2013-2015)	D Coates
The University of Western Australia, Ecosystem Research Group	Age structure of <i>Callitris</i> in the Carnarvon Range	Nil	S van Leeuwen, M Langley, N Gibson
University of Melbourne, Quantitative and Applied Ecology Group	Species distribution modelling in the Pilbara	Nil	S van Leeuwen
South Coast Natural Resource Management	Great Western Woodland vegetation map reconciliation project	\$100K	S van Leeuwen, R Coppen, C Bishop, B Bayliss
Roy Hill (Roy Hill Mine Offset)	Jartaku bilby enclosure proposal	\$58K	K Morris, S van Leeuwen, M Dzimirski, M Cowan
Rangelands Natural Resource Management - Pilbara Corridors	Biodiversity assets and landscape-scale management of the Fortescue River catchment	Nil	S van Leeuwen, K Morris
Murdoch University, School of Biological Sciences	Genetic studies of Pilbara EPBC Act listed vertebrate fauna	Nil	K Morris, D Pearson, S van Leeuwen
Office of the Environmental Protection Authority, Terrestrial Ecosystems Branch	A review of subterranean fauna assessment in Western Australia	Nil	S van Leeuwen, A Pinder
Main Roads Western Australia	Ecology and management of northern quoll in the Pilbara	\$25K	K Morris, J Dunlop, K Rayner
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 (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, F Carpenter, M Dzimirski

Partnership	Project Title	External Funding	DPaW Involvement
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
CSIRO Land and Water	Pilbara groundwater dependent ecosystem study	Nil	S van Leeuwen, A Pinder
CSIRO Ecosystem Sciences	Cost-effective conservation decisions to mitigate threats to Pilbara biodiversity	Nil	S van Leeuwen
CSIRO Ecosystem Sciences	Biodiversity modelling for BHP Billiton Iron Ore's Strategic Environmental Assessment in the Pilbara	Nil	S van Leeuwen
CSIRO Ecosystem Sciences, 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
Central Desert Native Title Service	Biological survey of the Birilburru Indigenous Protected Areas: phase 1 - Carnarvon Range	\$25K	S van Leeuwen, K Quinlan, M Langley, N Gibson, M Cowan, N Guthrie, A Pinder, L Gibson
BHP Billiton Iron Ore, Fortescue Metals Group (Cloudbreak Stage B Mine Offset)	Floristic survey of the Fortescue Marsh	\$45K, \$200K	S van Leeuwen, C McCormick, M Lyons, A Markey
BHP Billiton Iron Ore, Main Roads Western Australia	Ecology and management of Pilbara olive python in the Pilbara	BHP Billiton: \$50K, Main Roads: \$50K	D Pearson, S van Leeuwen
Atlas Iron	Ecology and management of the Pilbara leaf-nosed bat	\$350K	S van Leeuwen, L Gibson, K Morris
Atlas Iron (Mt Dove Offset), CSIRO Ecosystem Sciences	Strategic weed assessment for the Chichester subregion of the Pilbara	\$100K	S van Leeuwen
Atlas Iron	Investigating the interactions between feral predators in the Pilbara	\$300K	K Morris, S van Leeuwen
Atlas Iron, Pilbara Corridors, Rangelands NRM, CSIRO Ecosystem Sciences	Strategic weed risk assessment and implementation plan for the Chichester and Fortescue subregions of the Pilbara	\$385K	S van Leeuwen
Atlas Iron, Fortescue Metals Group, Main Roads Western Australia	Ecology and management of the northern quoll in the Pilbara	Atlas: \$50K (2010-2016), Fortescue: \$100K (2012-2021), Main Roads: \$25K	K Morris, S van Leeuwen, J Dunlop, K Rayner
Atlas Iron	Sponsorship of the 'Research directions for Pilbara leaf-nose bat' workshop	\$10K	S van Leeuwen, K Morris, L Gibson
Terrestrial Ecosystem Research Network (TERN)	TERN: ecoinformatics facility and development of ecological databases and portals	Nil	P Gioia
Rhodes College TN, St John's University NY	Phylogenetics and floral symmetry development of the core Goodeniaceae	Nil	K Shepherd
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, K Thiele

Partnership	Project Title	External Funding	DPaW Involvement
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
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
Woodside Energy	Taxonomic studies on Burrup flora	\$120K	R Butcher, S van Leeuwen, K Shepherd, J Wege
Western Australian Museum	Pilbara biological survey	Nil	A Pinder, L Gibson, M Lyons, AH 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
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
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 Adelaide	Wetland biological survey and monitoring: rotifer and cladoceran identifications	Nil.	A Pinder, K Quinlan, D Cale
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
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
The University of Western Australia	Genetic diversity of corals in the Montebello and Barrow Islands MPAs	Nil	S Field
The University of Western Australia	Assessing fish communities in Marmion Marine Park	Nil	K Friedman
Terrestrial Ecosystem Research Network (TERN)	TERN multiscale plot network: AusPlot Rangelands and SWATT	\$250K for SWATT, \$90K for AusPlots Rangelands	S van Leeuwen, N Casson, R Meissner, R Coppen
South Coast Natural Resource Management, Caring for Our Country, DPaW South Coast Region	Increasing native habitat through protection of EPBC species and ecological communities (dibbler recovery)	\$30K (2011-2013)	A Friend

Partnership	Project Title	External Funding		DPaW Involvement
Satterley Property Group	Factors associated with western ringtail possum (<i>Pseudochirus occidentalis</i>) persistence within retained habitat at development sites	\$400K (2009-2013)		K Morris
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
Fortescue Metals Group (Main Line Duplication Offset), Millennium Minerals (Golden Eagle Offset)	Bilby conservation and management in the Pilbara	\$100K (2012-2021), \$60K (2012-2017)		K Morris, F Carpenter, M Dziminski
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 (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, BHP Billiton	Seed collection zones for the Pilbara	\$400K		M Byrne, S van Leeuwen, D Coates
Rio Tinto	Identification Botanist position at the Western Australian Herbarium	\$114K		K Thiele
National Science Foundation (US)	Systematics and Biogeography of the Inocybaceae	\$19K		N Bougher
National Climate Change Adaptation Research Facility, Monash University, Griffith University, South Australian Research and Development Institute, Department of Environment and Resource Management (Qld), Natural Resources, Environment, the Arts and Sport (NT)	Building the climate resilience of arid zone freshwater biota: identifying and prioritising processes and scales for management	\$426K		A Pinder, K Quinlan
National Climate Change Adaptation Research Facility, Murdoch University, The University of Western Australia, Department of Water and CSIRO.	A risk assessment and decision framework for managing groundwater dependent ecosystems with declining water levels	\$325K		A Pinder, M Penniford
Murdoch University; Perth Zoo; Department of Environment and Heritage (SA); University of Western Australia	Woylie conservation research project	Nil		A Wayne, C Ward, M Maxwell
Murdoch University	Taxonomic studies of Western Australian marine plants	\$40K p.a. 2011-2013		J Huisman
Murdoch University (Centre for Fish, Fisheries & Aquatic Ecosystems Research), 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 Fish, Fisheries & Aquatic Ecosystems Research), Caring for our Country	Fish populations and invasive species of Vasse-Wonnerup Ramsar Site	\$215K		J Lane, A Clarke
Millennium Seedbank Project	Seed collection, storage and biology	\$128K p.a. to 2011, \$8K in 2012-2013		A Cochrane, D Coates

Partnership	Project Title	External Funding	DPaW Involvement
Chevron (Gorgon Gas Development, Net Conservation Benefit funding)	Cat eradication on Dirk Hartog Island	\$200K p.a. for five years	D Algar, M Onus
Future Farm Industries CRC	Management of weed and genetic risk in perennial landuse systems	\$257K for 2011-2014	M Byrne, B Macdonald
Fortescue Metals Group Ltd (Christmas Creek Water Management Offset)	Baiting feral cats on the Fortescue Marsh	\$600K	D Algar, S van Leeuwen, N Hamilton
Edith Cowan University	Spatial and temporal patterns in benthic invertebrate communities of the Walpole and Norralup 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
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
Shire of Christmas Island, Christmas Island National Park	Christmas Island cat and rat management plan (stage 2B)	\$450K	D Algar, N Hamilton
CSIRO and independent scientists	Explaining and predicting the occurrence of night parrots (<i>Pezoporus occidentalis</i>) using GIS and ecological modelling	\$38K	AH Burbidge
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 Ecosystem Sciences	Pilbara biological survey biodiversity GDM modelling/gap analysis: terrestrial fauna and wetland flora and fauna	Nil	A Pinder, N McKenzie, L Gibson, M Lyons, AH Burbidge
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, J Angus, S Garretson
North Australian Marine Research Alliance	Assessing spatial and demographic structure of anthropogenic mortality on Australasian marine turtles	\$300K (2012-2014)	S Whiting
Caring for our Country	Western Desert fire project	\$317K over two years	N Burrows, G Behn, C Rumery
Caring for our Country	Eradication of exotic rodents from six islands of high conservation value	\$890K 2010-2013	K Morris, R Palmer
BHP Billiton Iron Ore	Identification Botanist position at the Western Australian Herbarium	\$105K	K Thiele
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
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

Partnership	Project Title	External Funding	DPaW Involvement
Australian Institute of Marine Science, Australian National University	Ningaloo seasonal seaweeds	\$30K	S Wilson, K Murray, T Holmes
Australian Institute of Marine Science	Coral reef fish recruitment study	AIMS & ANU funded field trip	S Wilson, T Holmes
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
ARC Linkage, The University of Western Australia	Automation of species recognition and size measurement of fish from underwater stereo-video imagery	\$436K over three years, \$190K cash and in kind from partner organisations	S Wilson
ARC Linkage, The University of Western Australia, Chevron, Rio Tinto Iron Ore, Botanic Parks and Gardens Authority	Defining biologically significant units in spinifex (<i>Triodia</i> spp.) for improved ecological restoration in arid Australia	\$549K over four years	K Thiele, S van Leeuwen
ARC Linkage, 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, 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

Summary of Research Projects

Biogeography

DPaW Region	IBRA/IMCRA	NRM Region	Project Title	Page
Swan, South West	Swan Coastal Plain, Jarrah Forest	Avon	Biological Survey and Conservation Planning for the Swan Coastal Plain IBRA and adjacent Scarps (Dandaragan, Darling and Whicher).	30
South Coast	Mallee, Esperance Plains	South Coast	Biological survey of the Ravensthorpe Range	36
All DPaW Regions	All IBRA Regions	All NRM Regions	Development of ethically acceptable techniques for invertebrate wet-pit trapping	35
Kimberley	Victoria Northern, Bonaparte, Kimberley, Dampierland	Rangelands	Kimberley islands biological survey	36
Pilbara	Pilbara	Rangelands	Pilbara regional biological survey	37
All DPaW Regions	All IBRA Regions, All IMCRA Regions	All NRM Regions	Plant species richness and endemism within the south-western Australian Floristic Region	34
Goldfields, Wheatbelt, South Coast, Warren	Murchison, Wheatbelt, Jarrah Forest, Mallee, Esperance Plains	Wheatbelt, Rangelands, South Coast	South-Western Australia Transitional Transect (SWATT)	29
All DPaW Regions	All IBRA Regions	All NRM Regions	Western Australian flora surveys	31
All DPaW Regions	All IBRA Regions	All NRM Regions	Western Australian terrestrial fauna surveys	33

Animal Science

DPaW Region	IBRA/IMCRA	NRM Region	Project Title	Page
Pilbara	Pilbara	Rangelands	Improved fauna recovery in the Pilbara – Assessing the uptake of feral cat baits by northern quolls, and their associated survivorship	39
Pilbara, Goldfields	Pilbara, Gascoyne, Murchison	Rangelands	Barrow Island Threatened and Priority fauna species translocation program	48
Midwest	Carnarvon, Yalgoo	Rangelands	Cat Eradication on Dirk Hartog Island	40
Pilbara	Pilbara	Rangelands	Conservation and management of the bilby (<i>Macrotis lagotis</i>) in the Pilbara	44
South Coast, Warren	Jarrah Forest, Esperance Plains, Warren	South West, South Coast	Conservation of south coast threatened birds	51
Goldfields, Swan	Coolgardie, Swan Coastal Plain	Rangelands, Swan	Conservation of the graceful sun-moth	54
Pilbara	Pilbara	Rangelands	Decision support system for prioritising and implementing biosecurity on Western Australia's islands	43

DPaW Region	IBRA/IMCRA	NRM Region	Project Title	Page
Pilbara, Midwest, South Coast	Carnarvon, Gibson Desert, Murchison, Gascoyne,	Rangelands, Swan	Development of effective broad-scale aerial baiting strategies for the control of feral cats	57
Pilbara	Pilbara	Rangelands	Ecology and management of the northern quoll in the Pilbara	52
Wheatbelt	Avon Wheatbelt	Avon	Feral cat control and numbat recovery in Dryandra woodland and other sites	50
Pilbara, Swan	Pilbara, Swan Coastal Plain, Jarrah Forest	Rangelands, Swan	Genetic approaches for evaluating the contribution of the reserve system to fauna conservation	47
Kimberley, Pilbara	Northern Kimberley, Central Kimberley, Dampierland, Pilbara	Rangelands	Genetic assessment for conservation of rare and threatened fauna	45
South Coast	Jarrah Forest	South Coast	Gilbert's potoroo (<i>Potorous gilbertii</i>) recovery plan	58
Warren	Jarrah Forest	South West	Identifying the cause(s) of the recent declines of woylies in south-west Western Australia	54
Kimberley	Victoria Bonaparte, Northern Kimberley, Ord Victoria Plain, Central Kimberley	Rangelands	Impact of cane toads on biodiversity in the Kimberley	56
All DPaW Regions	Gascoyne	All NRM Regions	Improving the use of remote cameras as a survey and monitoring tool	41
Midwest	Geraldton Sandplains		Monitoring of threatened birds on Dirk Hartog Island	40
Goldfields	Gascoyne	Rangelands	Rangelands restoration: reintroduction of native mammals to Lorna Glen (Matuwa)	49

Plant Science and Herbarium

DPaW Region	IBRA/IMCRA	NRM Region	Project Title	Page
All DPaW Regions	All IBRA Regions	All NRM Regions	Biodiversity informatics at the Western Australian Herbarium	67
All DPaW Regions	All IBRA Regions, All IMCRA Regions	All NRM Regions	Biosystematics of fungi for conservation and restoration of Western Australia's biota	61
Midwest	Geraldton Sandplains	Northern Agricultural	Climate change risks for biodiversity and ecosystem function in species-rich shrublands	61
All DPaW Regions	All IBRA Regions, All IMCRA Regions	All NRM Regions	Conservation status and systematics of Western Australian <i>Acacia</i>	78
All DPaW Regions	All IBRA Regions, All IMCRA Regions	All NRM Regions	Development of interactive identification platforms and content	78
Wheatbelt	Avon Wheatbelt, Swan Coastal Plain	Northern Agricultural, Avon, Swan, South Coast	Genetic and ecological viability of plant populations in remnant vegetation	79
Midwest, Goldfields, Wheatbelt, Swan, South Coast	Yalgoo, Murchison, Geraldton Sandplains, Avon Wheatbelt, Coolgardie, Swan Coastal Plain, Mallee, Esperance Plains	Rangelands, Northern Agricultural, Avon, Swan, South West, South Coast	Genetics and biosystematics for the conservation, circumscription and management of the Western Australian flora	85
All DPaW Regions	All IBRA Regions, All IMCRA Regions	All NRM Regions	Herbarium collections management	65

DPaW Region	IBRA/IMCRA	NRM Region	Project Title	Page
			Interactive key and taxonomic studies of Myrtaceae tribe Chamelaucieae	60
Midwest, Wheatbelt, Swan, South Coast, South West, Warren	Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains	Rangelands, Northern Agricultural, Swan, South West, South Coast	Mating system variation, genetic diversity and viability of small fragmented populations of threatened flora, and other key plants of conservation importance	82
Kimberley, Pilbara	Victoria Bonaparte, Northern Kimberley, Ord Victoria Plain, Central Kimberley, Dampierland, Great Sandy Desert, Carnarvon, Little Sandy Desert, Gibson Desert, Gascoyne, Central Ranges	Rangelands	Resolving the systematics and taxonomy of <i>Tephrosia</i> in Western Australia	70
All DPaW Regions	Great Sandy Desert, Carnarvon, Gascoyne, Geraldton Sandplains, Avon Wheatbelt, Coolgardie, Swan Coastal Plain, Jarrah Forest, Hampton, Mallee, Esperance Plains, Warren	Rangelands, Northern Agricultural, Swan, South West, South Coast	Seed biology, seedbank dynamics and collection and storage of seed of rare and threatened Western Australian taxa	84
All DPaW Regions	All IBRA Regions	All NRM Regions	Strategic taxonomic studies in families including <i>Amaranthaceae</i> and <i>Fabaceae</i> (<i>Ptilotus</i> , <i>Gomphrena</i> , <i>Swainsona</i>) and other plant groups	63
Wheatbelt, Swan, South Coast, South West, Warren	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Esperance Plains, Warren	Northern Agricultural, Swan, South West, South Coast	Strategic taxonomic studies in families including <i>Epacridaceae</i> , <i>Rafflesiaceae</i> , <i>Rhamnaceae</i> and <i>Dilleniaceae</i>	69
All DPaW Regions	All IBRA Regions	All NRM Regions	Systematics of the triggerplant genus <i>Stylidium</i>	73
All DPaW Regions	All IBRA Regions	All NRM Regions	Taxonomic resolution and description of new plant species, particularly Priority Flora from those areas subject to mining in Western Australia	77
Kimberley, Pilbara, Swan, South Coast, South West, Warren	Victoria Bonaparte, Northern Kimberley, Central Kimberley, Dampierland, Gascoyne, Geraldton Sandplains, Swan Coastal Plain, Jarrah Forest, Esperance Plains, Warren	Rangelands, Northern Agricultural, Swan, South West, South Coast	Taxonomic review and floristic studies of the benthic marine algae of north-western Australian and floristic surveys of Western Australian marine benthic algae	74
All DPaW Regions	Geraldton Sandplains, Avon Wheatbelt, Coolgardie, Swan Coastal Plain, Mallee, Esperance Plains, Warren	Northern Agricultural, Avon, Swan, South West, South Coast	Taxonomic studies on native and naturalised plants of Western Australia arising from biological survey	69
All DPaW Regions	All IBRA Regions	All NRM Regions	Taxonomy of selected families including legumes, grasses and lilies	71
All DPaW Regions	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren	All NRM Regions	Taxonomy of undescribed taxa in the <i>Eriaceae</i> subfamily <i>Styphelioideae</i> , with an emphasis on those of conservation concern	68

DPaW Region	IBRA/IMCRA	NRM Region	Project Title	Page
Midwest, Wheatbelt, Swan, South Coast, Warren	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren	Northern Agricultural, Swan, South West, South Coast	Temperature thresholds for recruitment in south-west Western Australian flora	73
All DPaW Regions	All IBRA Regions	All NRM Regions	The Western Australian Herbarium's specimen database	64
All DPaW Regions	All IBRA Regions	All NRM Regions	The Western Australian Plant Census and Australian Plant Census	63
Kimberley, Pilbara, Midwest, Swan, South Coast, South West, Warren	Victoria Bonaparte, Northern Kimberley, Central Kimberley, Dampierland, Geraldton Sandplains, Swan Coastal Plain, Jarrah Forest, Esperance Plains, Warren	Rangelands, Northern Agricultural, Swan, South West, South Coast	The Western Australian marine benthic algae online and an interactive key to the genera of Australian marine benthic algae	76
Midwest, Goldfields, Wheatbelt, Swan, South Coast, South West	Avon Wheatbelt, Jarrah Forest, Esperance Plains	Rangelands, Northern Agricultural, Avon, Swan, South West, South Coast	The population ecology of critically endangered flora	83
Midwest, Wheatbelt, South Coast, South West	Geraldton Sandplains, Avon Wheatbelt, Coolgardie, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren	Northern Agricultural, Avon, Swan, South West, South Coast	Translocation of critically endangered plants	80

Ecosystem Science

DPaW Region	IBRA/IMCRA	NRM Region	Project Title	Page
Warren	Jarrah Forest	South West	Burning for biodiversity: Walpole fine-grain mosaic burning trial	103
Goldfields, Wheatbelt, Warren	Avon Wheatbelt, Coolgardie, Mallee, Warren	Wheatbelt, Rangelands, South Coast	Climate-resilient vegetation of multi-use landscapes: exploiting genetic variability in widespread species	93
South West, Warren	Jarrah Forest, Warren	Swan, South West	Evaluation of key soil indicators of sustainability in Australian mediterranean forests (Indicators 4.1d, 4.1e)	108
Swan, South West, Warren	Jarrah Forest, Warren	Swan, South West	FORESTCHECK: Integrated site-based monitoring of the effects of timber harvesting and silviculture in the jarrah forest	101
			Fire behavior and fuel dynamics in coastal shrublands	90
Kimberley	Northern Kimberley	Rangelands	Fire regimes and biodiversity decline in the Kimberley test	99
Goldfields, Wheatbelt, South Coast	Yalgoo, Avon Wheatbelt, Coolgardie, Mallee	Wheatbelt, Rangelands	Fire regimes and impacts in transitional woodlands and shrublands	98
Pilbara, Midwest, Goldfields, Wheatbelt, South Coast, South West, Warren	Murchison, Geraldton Sandplains, Avon Wheatbelt, Coolgardie, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains	Wheatbelt, Rangelands, Northern Agricultural, South West, South Coast	Genetic analysis for the development of vegetation services and sustainable environmental management	110

DPaW Region	IBRA/IMCRA	NRM Region	Project Title	Page
Swan	Jarrah Forest	Swan, South West	Hydrological response to timber harvesting and associated silviculture in the intermediate rainfall zone of the northern jarrah forest	107
South West, Warren	Jarrah Forest	Swan, South West	Identification of seed collection zones for rehabilitation	100
Swan	Jarrah Forest	Swan	Landscape and fire management interactions and their effects on distribution of invertebrate biodiversity	107
			Long term response of jarrah forest understorey and tree health to fire regimes	91
Warren	Warren	South West	Long-term stand dynamics of regrowth karri forest in relation to site productivity and climate	95
Midwest, Wheatbelt, South Coast	Geraldton Sandplains, Avon Wheatbelt, Esperance Plains	Wheatbelt, Agricultural, Coast	Management of environmental risk in perennial land use systems	104
Swan, South West, Warren	Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren	Swan, South West, South Coast	Management of invertebrate pests in forests of south-west Western Australia	96
Warren	Warren	South West, South Coast	Monitoring post-fire effects from the 2001 Nuyts wildfire	102
Kimberley	Northern Kimberley	Rangelands	North Kimberley Landscape Conservation Initiative: monitoring and evaluation	92
Goldfields	Gascoyne, Murchison	Rangelands	Project Rangelands Restoration: developing sustainable management systems for the conservation of biodiversity at the landscape scale in rangelands of the Murchison and Gascoyne bioregions—managing fire and introduced predators	105
Wheatbelt, South Coast, Warren	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren	Wheatbelt, Agricultural, South West, Coast	Protecting the safe havens: will granite outcrop environments serve as refuges for flora threatened by climate change?	97
Warren	Jarrah Forest, Warren	South West	Responses of terrestrial vertebrates to timber harvesting in the jarrah forest	89
Warren	Warren	South West	Restoring natural riparian vegetation systems along the Warren and Donnelly Rivers	88
Warren	Warren	South West	The effect of wildfire on forest fungi	109
Midwest, Wheatbelt, Swan, South Coast, South West	Jarrah Forest, Mallee, Warren	Northern Agricultural, South West, South Coast	Understanding the changing fire environment of south-west Western Australia	87

Wetlands Conservation

DPaW Region	IBRA/IMCRA	NRM Region	Project Title	Page
Wheatbelt	Avon Wheatbelt	Avon	Advancing the hydrological understanding of key Wheatbelt catchments and wetlands to inform adaptive management	115
			Assessing and managing threats to flora in wetland communities	118
Swan, South West, Warren	Jarrah Forest, Warren	Swan, South West, South Coast	Monitoring stream biodiversity (KPI 20 of the Forest Management Plan)	120

DPaW Region	IBRA/IMCRA	NRM Region	Project Title	Page
South West	Jarrah Forest, Warren	Swan, South West	Responses of aquatic invertebrate communities to changing hydrology and water quality in streams and significant wetlands of the south-west forests of Western Australia.	112
Midwest, Wheatbelt, Swan, South Coast, South West, Warren	Murchison, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Esperance Plains, Warren	Wheatbelt, Northern Agricultural, Avon, Swan, South West, South Coast	South West Wetlands Monitoring Program (SWWMP)	113
			Taxonomy, zoogeography and conservation status of aquatic invertebrates	116
			Understanding peat wetland resilience: evaluating the impact of climate and land-use change on the hydrodynamics and hydrogeochemistry of peat wetlands in the Warren (Muir-Byenup) District	117
All DPaW Regions	All IBRA Regions	All NRM Regions	Western Australian wetland fauna surveys	119

Marine Science

DPaW Region	IBRA/IMCRA	NRM Region	Project Title	Page
			Access and human use at Penguin Island and related implications for management of Marine Park assets and visitor risk	124
Kimberley	Bonaparte Gulf, Kimberley, Northwest Shelf, Cambridge-Bonaparte, Canning, King Sound		Distribution and abundance estimate of Australian snubfin dolphins (<i>Orcaella heinsohni</i>) at a key site in the Kimberley region, Western Australia	123
Pilbara	Pilbara, Ningaloo	Rangelands	Effects of the Gorgon Project dredging program on the marine biodiversity of the Montebello/Barrow Islands marine protected areas	134
			Habitat use, distribution and abundance of coastal dolphin species in the Pilbara	121
			Improving the understanding of West Pilbara marine habitats and associated taxa: their connectivity and recovery potential following natural and human induced disturbance	125
Pilbara	Ningaloo	Rangelands	Interactive effects of fishing and climate change on coral reef fish populations	136
Kimberley, Pilbara	Northwest Shelf	Rangelands	North West Shelf Flatback Turtle Conservation Program strategic plan	131
Pilbara	Pilbara (Offshore), Pilbara (Nearshore)	Rangelands	Review, assess and summarise historical data relevant to the management of the proposed Dampier Archipelago Marine Park and Regnard Marine Management Area	130
Warren	WA South Coast	South Coast	Spatial and temporal patterns in benthic invertebrate communities of the Walpole and Nornalup Inlets Marine Park	135
Swan	Central West Coast	Swan	Spatial and temporal patterns in the structure of intertidal reef communities in the marine parks of south-western Australia	137

DPaW Region	IBRA/IMCRA	NRM Region	Project Title	Page
Midwest	Shark Bay	Rangelands	Spatial variation in the functional morphology of mangroves in the Shark Bay World Heritage Area	134
All DPaW Regions	All IBRA Regions, All IMCRA Regions	All NRM Regions	The Western Australian Marine Monitoring Program (WAMMP)	129
			The influence of macroalgal fields on coral reef fish	127
			Understanding movements and identifying important habitats of sea turtles in Western Australia	128
Kimberley, Pilbara	Oceanic Shoals, Bonaparte Gulf, Kimberley, Northwest Shelf, Cambridge-Bonaparte, Canning, King Sound, Eighty Mile Beach	Rangelands	WAMSI 2: Kimberley Marine Research Program	132

Ecoinformatics

DPaW Region	IBRA/IMCRA	NRM Region	Project Title	Page
All DPaW Regions	All IBRA Regions, All IMCRA Regions	All NRM Regions	Online GIS biodiversity mapping (NatureMap)	139
All DPaW Regions	All IBRA Regions, All IMCRA Regions	All NRM Regions	Provision of authoritative names of Western Australian taxa	138

Research Activities

Biogeography

Program Leader: Lesley Gibson

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

SP 2013-003 South-Western Australia Transitional Transect (SWATT)

Team

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

Context

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

Aims

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

Progress

- Quadrat data has been provided and published on the Terrestrial Ecosystems Research Network's (TERN) data storage facility
- Data analysis has been completed
- A final project report has been produced examining floristic patterning on sand plain vegetation communities along the SWATT, paying particular attention to compositional change and how such change is being influenced by edaphic attributes.

- Plant specimens have been labelled and are ready to lodge for vouchers in the WA Herbarium

Management implications

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

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

Future directions

- Through spatially explicit ordination approaches investigate patterns of beta diversity and complementarity in patterns observed with respect to those patterns previously identified for the Banded Iron Formation ranges of the Yilgarn.
- Seek additional resources to expand research activities along the SWATT to capture patterns of biodiversity amongst various faunal groups and across other vegetation types.

SP 2012-032 Biological Survey and Conservation Planning for the Swan Coastal Plain IBRA and adjacent Scarps (Dandaragan, Darling and Whicher).

Team

G Keighery

Context

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

Aims

- Prepare a new 1: 250,000 and 1: 50,000 vegetation complex maps for the Swan Coastal Plain.
- Prepare reports and publications on conservation reserves and offset acquisitions (proposed and actual).
- Using volunteers, survey and report on areas of interest for conservation planning of the Perth region and greater Swan Coastal Plain IBRA region.

Progress

- Vegetation complex mapping of Bunbury to Busselton prepared at 1: 250 000
- Whicher Scarp interface with forest mapping underway
- Expert witness for State Administration Tribunal
- Paper detailing flora of Yanchep National Park in press
- Surveys of newly acquired bushland at Chandala completed

- Several reports on bushland in the Kemerton area (offsets), western Suburbs of Perth, Harvey River and Serpentine

Management implications

- A better understanding of the conservation values of remnant and intact bushland areas forms the basis for improved land use planning and decision making for biodiversity conservation on the Swan Coastal Plain.
- Provides data on guidance statements for EIA assessments of Swan Coastal Plain and Perth/Peel Strategic Assessment

Future directions

- Update information on and prepare monitoring sites for the south Bunbury greenways corridor using volunteers in association with SWIC NRM, City of Bunbury and Department of Parks and Wildlife SW Region in spring 2015.
- Continue collation of vegetation complex mapping

SP 2012-005 Western Australian flora surveys

Team

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

Context

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

Current projects include:

- AusPlots Rangeland survey sites as a baseline for long-term monitoring in collaboration with the Terrestrial Ecosystems Research Network (TERN). This AusPlots WA campaign has focused on the Coolgardie and Murchison Bioregions in the Great Western Woodlands.
- Flora survey of the Katjarra (Carnarvon Range) Indigenous Protected Area (IPA) in collaboration with the Birriliburu Native Title Claimants to aid future management. Survey campaign funded by Central Desert Native Title Services and undertaken in collaboration with Birriliburu Rangers and Bush Heritage Australia.
- Floristic survey and mapping of the halophyte-dominated communities of the Fortescue Marsh.
- Vegetation mapping data for the Great Western Woodlands and Indian Ocean Drive to inform natural resource management and land use planning.
- Black spot flora survey of the PETERSWALD 1:100,000 map sheet, funded by Federal Department of Environment.

Aims

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

- Undertake a floristic survey of the PETERSWALD 1:100,000 map sheet which has previously been very poorly surveyed.

Progress

- AusPlots Rangeland sites were established and sampled in the Coolgardie, Pilbara and Little Sandy Desert bioregion. Thirty of these sites were associated with the Great Western Woodlands Supersite at Credo or the South West Australian Transitional Transect (SWATT).
- A total of 160 sandplain heath plots at 10 locations along the SWATT were sampled and data supplied to TERN.
- Undertaken a field trip to the Katjarra IPA where twenty permanent floristic plots were established and targeted surveys for species of interest were undertaken. Identification of the collections during the May 2014 field trip is continuing. A draft of the flora report for the Katjarra survey has been prepared.
- Fieldwork for the Fortescue Marsh survey and mapping project was completed in September 2014. All species identifications have been completed and databased, and progress reports prepared for both BHP Billiton Iron Ore and the Fortescue Metals Group. Two new taxa (*Dysphania* sp. Fortescue Marsh (A. Markey & S. Dillon FM 9709 and *Samolus* sp. Fortescue Marsh (A. Markey & R. Coppen FM 9702) have been formally phrase named, and a manuscript describing the *Dysphania* as a new species is nearing completion. Floristic community analysis and mapping is in progress.
- The Vegetation Map Reconciliation project for the Great Western Woodlands was completed, uploaded onto NatureMap and successfully delivered to South Coast NRM.
- The Vegetation Map Reconciliation project for Indian Ocean Drive between Lancelin and Jurien was completed and successfully delivered to the WA Local Government Association and Department of Planning.
- Flora survey of PETERSWALD has been completed, a draft report has been prepared.

Management implications

- The Katjarra IPA survey has more than doubled the number of known plant taxa from the area, and has identified a number of significant range extensions, new populations of Priority Flora and one possible new taxon. Data from this survey will inform future management of the IPA.
- Data from the Fortescue Marsh floristic survey and vegetation mapping project will provide documentation of the conservation values of the Marsh and input into ongoing management, land use planning and environmental approvals processes for this very important arid zone wetland.
- Data from AusPlots will ultimately be web-based and freely available, creating the opportunities for management to be informed by researchers who: i) interrogate vegetation structure, composition and metagenomics, and soil structure and metagenomics; ii) use the plots as ground-truth for remote sensing purposes; iii) potentially cross-correlate cover and/or 3D imagery with biomass/carbon cycling; and iv) revisit the sites to ground-truth change and outline vegetation dynamics.
- Data compiled via the Great Western Woodland and Indian Ocean Drive vegetation map reconciliation projects will primarily be used to inform land use planning and natural resource management activities. The maps provide information on vegetation values associated with land rezoning plans, fire management activities and impact assessment from resource development. The derived products also highlight the knowledge gaps associated with the coverage of existing vegetation mapping products for the two biological significant regions.
- The survey of the PETERSWALD area increased the known flora known from three to over 350 taxa. Data will be made available via NatureMap and WA Herbarium database. This will provide information on the flora values of the area and assist in land use planning and impact assessments for resource development.

Future directions

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

SP 2011-021 Western Australian terrestrial fauna surveys

Team

M Cowan, L Gibson, AH Burbidge, D Pearson

Context

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

Aims

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

Progress

- In July 2014, a six-day biodiversity survey of Champagny Island off the Northern Kimberley coast was conducted in collaboration with the Kimberley Region and Dambimangari rangers. Several previously unrecorded species were detected including two mammals, the endemic Kimberley rock rat (*Zyomys woodwardi*) and water rat (*Hydromys chrysogaster*), and eight reptile species.
- Also in July 2014, as a component of the North-Kimberley Landscape Conservation Initiative, 12 vegetation condition monitoring sites on Uwins, St Andrew and Storr islands (4 on each) were also established. As the islands are less altered by fire and other disturbance processes, they provide important benchmarks against which to compare changes in vegetation cover and condition of the mainland monitoring sites, and thereby the effectiveness of management actions.
- In August/September 2014, a survey in a remote section of the Great Victoria Desert (GVD) was undertaken (Peterswald Hill 1:100 000 map sheet) in collaboration with the Goldfields Region. This survey is the first of at least three surveys in the GVD, which will help to fill a knowledge gap with regard to the biota of this poorly-known area.

Management implications

- The immediate aims of the individual projects vary depending on the needs of the funding source, but usually contribute to improved species distributional and ecological understanding, prioritisation of conservation actions by local managers, and/or the assessment of potential environmental impacts of land use proposals. Individual survey projects assist regional conservation and land managers to understand local biodiversity patterning and its underlying drivers, and permit the use of this information to assess environmental impacts, prioritise conservation actions, set biodiversity targets, establish baselines for monitoring and monitor change. The combination of surveys enable improved understanding of species distributions and habitat requirements at a state level, thus contributing to bioregional analyses, reviews

of species' conservation status and analyses of the relationships between species and broad-scale gradients and threats such as climate change.

Future directions

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

- Another survey in the Great Victoria Desert region (Colville map sheet)
- Bush Blitz survey of the Kiwirrkurra IPA

SP 2011-010 Plant species richness and endemism within the south-western Australian Floristic Region

Team

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

Context

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

Aims

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

Progress

- The bioregionalisation analysis was repeated on a 2015 data snapshot using the same methodology as 2004.
- Analysis has now been completed. Results have been evaluated and are currently being written up.

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

- Produce manuscript for review.

SP 2010-005 Development of ethically acceptable techniques for invertebrate wet-pit trapping

Team

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

Context

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

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

Aims

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

Progress

- All field and laboratory work have been completed
- Analysis of numbers of bycatch (small reptile and mammals) from final Dryandra field trials show no sampling bias towards the trial chemistry of ethanol/propylene glycol
- Molecular assessment of both vertebrate and invertebrate samples from differing concentrations of ethanol and propylene glycol solutions has been undertaken by Science and Conservation Division staff. While the highest quality DNA was extracted from 100% ethanol samples, material from 80% ethanol and 20% propylene glycol was successfully amplified for the CO1 mitochondrial gene and sequenced. Consequently this material would be suitable for both bar coding and population genetics.
- Models of evaporation rates for ethanol/propylene glycol chemistry have been calculated under both controlled and field conditions. In conjunction with a modified trap the system should be viable in the field for periods of up to 40 days, dependant on ambient conditions and the volume of the traps
- Two reports from lab and field trials have been completed

Management implications

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

Future directions

- Verify that both vertebrate and invertebrate material is suitable for morphological and molecular studies after immersion in ethanol/propylene glycol preserving solution.

- Assess quality of molecular fixation from final field trial.
 - Discuss implications of all trials and findings with the Department's Animal Ethics Committee.
 - If methods are approved by the Animal Ethics Committee, assist Regions involved in invertebrate wet pit sampling to implement new methods where appropriate.
 - Complete report on all results and findings, publish outcome in a peer-reviewed journal.
-

SP 2007-006 Biological survey of the Ravensthorpe Range

Team

N Gibson

Context

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

Aims

Identify and quantify the botanical diversity of the Ravensthorpe Range.

Progress

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

Management implications

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

Future directions

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

SP 2007-001 Kimberley islands biological survey

Team

L Gibson, M Cowan, M Lyons, G Keighery

Context

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

Aims

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

Progress

- The final hard back volume “Biodiversity Values of Selected Kimberley Islands, Western Australia - Records of the Western Australian Museum, Supplement 81” edited by Lesley Gibson, Susan Yates and Paul Doughty has been published by the Western Australian Museum and is ready for distribution.

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

- Distribution of the hard back volume.
- All data made available via NatureMap.
- Continue knowledge transfer activities, including presentations to community groups.

SP 2004-002 Pilbara regional biological survey

Team

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

Context

The Pilbara is an economically important region in Western Australia, with major and expanding mineral extraction and pastoral industries. Effective biodiversity conservation is required to minimise the adverse impacts of these activities and other threatening processes, such as altered fire regimes on the Pilbara's diverse flora and fauna. This survey addresses problems of incomplete knowledge of biodiversity (composition, patterns, status and trend) for nature conservation planning, including conservation reserve system gaps and weed invasions. Sampling includes reptiles, frogs, small ground mammals, bats, birds, arachnids, beetles, ants and aquatic invertebrates including stygofauna, wetland and terrestrial flora and soils, to overcome low cross-taxon congruence in biodiversity models.

Aims

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

Progress

- A further paper was published on the riparian flora and plant communities (Part B of Supplement 78, Records of the Western Australian Museum)
- The final paper examining compositional patterns of the terrestrial fauna, and wetland flora and fauna, as well as conservation reserve representativeness, was accepted for publication.
- The survey team are providing data, publications, presentations and advice on the survey's findings to a range of local, regional and national stakeholders, including the pastoral and mining industry, Departmental Pilbara staff, EPA/OEPA, Commonwealth agencies as well as the wider conservation, science and environmental consultancy communities.

Management implications

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

Future directions

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

Animal Science

Program Leader: Keith Morris

Applied research undertaken by the Animal Science Program seeks to understand the factors and processes that are critical for the conservation of Western Australia's rich and unique native fauna. The major objectives of the program are to ensure the persistence of threatened species through local and landscape-scale management actions, including reducing key threats such as predation by foxes and feral cats, inappropriate fire

regimes, competition and predation by introduced rodents on islands, as well as assessing cane toad impacts and reconstructing the fauna of rangeland and arid areas.

SP 2015-016 Improved fauna recovery in the Pilbara – Assessing the uptake of feral cat baits by northern quolls, and their associated survivorship

Team

M Cowan, N Thomas, J Angus, S Garretson, K Morris, H Anderson, K Rayner

Context

The northern quoll (*Dasyurus hallucatus*) is one of seven terrestrial mammal species that has declined in the Pilbara over the last 100 years. Predation by feral cats is regarded as one of the most significant threatening processes for this Vulnerable listed species. The recent development of the *Eradicat* bait provides an opportunity to control feral cats at a landscape scale in the Pilbara. However knowledge of the diet and laboratory trials suggest that northern quolls may be at some risk from ingestion of toxic feral cat baits. This risk needs to be examined in a field situation where alternative prey items for quolls may reduce the risk from toxic bait ingestion. This project is funded from a Rio Tinto *EPBC Act* offset condition.

Aims

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

Progress

- Finalised funding arrangements and project design with Rio Tinto.
- Field work commenced in May 2015.
- 21 quolls radio-collared at the Yarraloola site (cat baited) and 2 quoll radiocollared at the Red Hill (unbaited site).
- Baiting of a 20,000 ha area at Yarraloola undertaken in early July.
- As at August 2015, no quolls had died as a result of cat bait ingestion, most mortalities were associated with feral cat predation.

Management implications

- The outcomes of this trial will determine how the feral cat bait *Eradicat* will be used in the Pilbara for fauna conservation programs at a landscape level.
- If it is shown that cat baiting does not present a risk to northern quolls, further cat control programs in the Pilbara can be contemplated.

Future directions

- Finalise cat baiting trial at Yarraloola / Red Hill, remove radio-collars from quolls.
 - Prepare report for Rio Tinto.
 - Commence planning for the longer term monitoring of northern quoll population at Yarraloola with implementation of operational cat baiting program.
-

SP 2014-003 Cat Eradication on Dirk Hartog Island

Team

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

Context

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

Aims

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

Progress

- Construction of temporary accommodation at the southern campsite (Herald Bay), including accommodation and equipment storage, has been completed. Construction of the northern campsite at Sandy Point is underway.
- Monitoring track access in both the southern and northern sections and installation of camera traps has now been completed.
- Barrier fence construction was completed in August 2014.
- The first baiting operation was undertaken late May 2014 and resulted in a 90% plus reduction in cat numbers south of the barrier fence. Baiting north of the barrier fence was undertaken in late May 2015 and is currently being assessed.

Management implications

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

Future directions

- Undertake seasonal monitoring for feral cat presence across the island and instigate trapping programs/control effort where warranted.
- It is anticipated that cats will have been eradicated by mid 2016, with confirmation after extensive monitoring by mid 2018.

SP 2013-021 Monitoring of threatened birds on Dirk Hartog Island

Team

AH Burbidge

Context

This project will develop and implement a monitoring program for the three extant threatened bird species on Dirk Hartog Island (DHI): (DHI southern emu-wren, DHI rufous field-wren, and DHI white-winged fairy-wren). This will allow assessment of the distribution, status and population trends of these species, and enable monitoring of change in relation to management actions.

Aims

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

Progress

- Most historical records have been compiled and mapped.
- Vegetation data (including nadir photographs to estimate vegetation cover) have been gathered at 30 sites, along with bird occurrence data.
- Trials of distance sampling techniques have been planned, and will be implemented in 2015-16.
- A preliminary phylogenetic analysis has been carried out for the DHI Rufous Fieldwren, in collaboration with staff at the WA Museum.

Management implications

This baseline monitoring will assist in interpreting the response of the DHI extant fauna to removal of goats and feral cats, and weed control. It is clear already that the Southern Emu-wren is much less common in the southern part of the island, where grazing pressure has been more intensive in the past.

Future directions

- Use distance sampling to provide estimates of population density for each of the threatened bird taxa.
- Develop a monitoring protocol based on the distance sampling data, and then field test the protocol.
- Continue phylogenetic analyses to assist in clarification of the conservation status of each of the bird species.

SP 2013-005 Improving the use of remote cameras as a survey and monitoring tool

Team

N Thomas, M Cowan, S Garretson

Context

The use of camera traps is often regarded as an effective tool for fauna survey and monitoring with the assumption that they provide high quality, cost effective data. However, our understanding of appropriate methods for general survey and species detection, particularly in the small to medium sized range of mammals, remains poorly understood. Within Parks and Wildlife use of camera traps to date has usually been restricted to simple species inventories or behavioural studies and beyond this there has been little assessment of deployment methods or appropriate analytical techniques. This has sometimes led to erroneous conclusions being derived from captured images. Camera traps have the potential to offer a comparatively reliable and relatively unbiased

method for monitoring medium to large native and introduced mammal species throughout the state, including a number of significant cryptic species that are currently not incorporated under the Western Shield fauna monitoring program. However, research is required to validate and test different survey designs (temporal and spatial components) and methods of deploying camera traps, and to interpret the results in a meaningful way. In particular, work is needed to determine how best to use remote cameras to provide rigorous data on species detectability, and species richness and density.

Aims

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

Progress

- Completed analysis of species relative abundance from cameras deployed during a known removal event (translocation of woylies to Perup), which showed the camera array method is sensitive enough to detect changes in relative abundance of a species.
- Quantified the camera effort required to detect all species (mammals) within Dryandra, which can be extrapolated to other reserves.
- Continue to provide advice on camera trap survey methodology to other sections within Parks and Wildlife, Tertiary institutions, Industry and NGO's.
- Completed a full 12 month trial in Dryandra which has established base line detection rate data for all known critical weight range mammals. This has enabled a preliminary assessment of spatial and temporal patterns for all taxa of primary interest.
- Analysed species accumulation data which shows a high degree of consistency as well as defining minimum effort required to inventory fauna of critical weight range size and above.
- Advice provided to the Woylie Recovery Team and Dryandra Management Team both for woylie and numbat occurrence and prevalence of pest species within Dryandra.
- Assessment of a new open source Access database (CPW Photo Warehouse) which, with a few minor script updates, appears to be a significant improvement over other open source Access data bases reviewed to date.

Management implications

- Camera traps appear to be an effective tool for detecting a suite of species currently not adequately monitored by the Western Shield monitoring program. Their use should be considered for operational use in the Western Shield monitoring program, either to complement the trapping program, or as a separate fauna monitoring tool.
- A standardised camera mounting method that is cohesive and repeatable between sites should be adopted for monitoring purposes.
- Camera traps consistently detect species that are not currently censused using most other standard detection/monitoring methods, and provide an effective mounting method for these species.
- The Access database CPW Photo Warehouse (<http://cpw.state.co.us/learn/Pages/ResearchMammals.aspx>) has greater functionality over previous reviewed databases, particularly as images can be out-sourced and analysed as part of potential citizen science program.
- The Dryandra work undertaken so far has excellent potential to be developed into a citizen science project that could continue to provide important data on the status of mammalian fauna while engaging a number of people in a variety of meaningful tasks associated with the maintenance, management and analysis of camera trap data.
- Reconyx camera traps (models HC600 and PC900) continue to be the most effective camera traps for departmental requirements commercially available and remain recommended for Departments use.

Future directions

- 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.
- Develop Dryandra camera trap work as a monitoring technique for cat bait effectiveness trials, and as a model citizen science project.
- Continue work on reviewing and/or modifying open source Access databases (particularly CPW Photo Warehouse) as they become available so that their functionality better suits the Department's needs.
- Continue to undertake desktop reviews of new camera traps (particularly cameras with video capability) as they become available to determine if any new models are better suited to the Department's needs.

SP 2013-001 Decision support system for prioritising and implementing biosecurity on Western Australia's islands

Team

K Morris, C Lohr, L Gibson, Dr J Brotankova (James Cook University), Distinguished Professor R Pressey (James Cook University, Australian Research Council Centre of Excellence for Coral Reef Studies), Dr A Wenger (James Cook University)

Context

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

Aims

- Develop a single comprehensive database on Pilbara island characteristics, fauna and flora values, and threats.
- Develop an operational decision support software for day-to-day use in making accountable and cost-effective decisions about where to spend limited funding on management of islands to promote the persistence of native species.
- Enable accountable and cost effective decisions that aid the conservation of Western Australia's islands and native species.

Progress

- Pilbara island database: 99% available historical data entered; new data from Pilbara Regional Staff regularly entered.
- Presentation at Island Arks Symposium III.
- Paper addressing changes in vegetation cover before, during and after rodent eradications on the Montebello Islands published.

- First version of software presented to Pilbara Regional Staff for review. Optimisation code published. Revised version of the software being developed.
- Expert data elicitation on abundance of native species and threats on Pilbara islands is complete.
- Field work for habitat mapping complete. Satellite data analysis and map generation in progress.
- Expert elicitation for island biosecurity modelling using Bayesian Belief Networks is complete.
- Workshops with environmental economists and ecologists to address data scarcity issues in progress.

Management implications

- The decision support software will result in more cost effective biosecurity management of island conservation reserves.
- A single comprehensive and easily accessible database on Pilbara island characteristics, biodiversity values and threats will facilitate island planning and management.
- Identification of priorities with regard to quarantine, surveillance, and biological survey on Pilbara islands.
- Identification of invasive species control or eradication priorities for Pilbara islands.

Future directions

- Use habitat maps to model native species distributions and assemblages.
- Use habitat maps to identify gaps in island biodiversity knowledge and survey history.
- Formulate island management cost model and sub-model components.
- Formulate species population growth model and sub-model components.
- Formulate the effectiveness of management actions model and sub-model components.
- Use island biosecurity Bayesian Belief Network to formulate island surveillance and quarantine model and sub-model components.
- Workshops with island managers to review revised model parameters and formulation.
- Test the decision support tool and train managers in application of the model.
- Seek opportunities to expand islands database to include Kimberley islands.

SP 2012-035 Conservation and management of the bilby (*Macrotis lagotis*) in the Pilbara

Team

M Dziminski, F Carpenter, K Morris

Context

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

Aims

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

Progress

- Population viability analysis on how much land area is required to create reserves for bilbies completed and submitted for publication, and is in the review process.
- The link between NatureMap and the Pilbara Threatened Fauna User contributable online database system (<http://dpaw.gaiaresources.com.au/bdrs-core/home.htm>) has been implemented and is working. There are 2731 records from the Pilbara Threatened Fauna Database that are being ported directly into NatureMap.
- Habitat modelling is being performed in collaboration with other Parks and Wildlife scientists. This work is almost complete and will be submitted for publication in the next 2 months.
- Using the current technique of 2 ha plots, 578 plots targeted in likely bilby habitat have been surveyed across the Pilbara for the presence of bilbies. Evidence of bilbies was recorded at 172 of the surveyed plots.
- Two RPA (Remotely Piloted Aircraft) were trialled to survey for bilbies in May 2015. This data is currently being analysed.
- The fine scale population monitoring technique using scats collected quantitatively to genotype individuals has been developed and refined, and trialled at five locations. This work is being analysed and prepared for publication as a standard technique for monitoring abundance of bilbies.
- Five populations are now being monitored using the above technique, in collaboration with stakeholders.
- 2014-15 saw a significant increase in a public awareness campaign for bilbies in the Pilbara with information sessions and public presentations being delivered at Port Hedland, Newman and Millstream, as well as radio and newspaper articles.
- Poster and Information Sheets continued to be distributed to the public in the Pilbara.

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 elsewhere, 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

- Continue to trial and refine remotely piloted aircraft to survey for bilbies.
- Continue a second year of monitoring at the five populations pending funding.
- Include more populations to the long-term monitoring program, developing more collaborations with stakeholders to monitor bilbies in their tenure, pending funding.

SP 2012-034 Genetic assessment for conservation of rare and threatened fauna

Team

K Ottewell, M Byrne, K Morris, D Coates

Context

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

Aims

- Resolve taxonomic boundaries of Western Australian bandicoots (*Isoodon* sp.), particularly *I. auratus* and *I. obesulus* and their subspecies, to determine appropriate conservation rankings.
- In collaboration with Brian Chambers (UWA) investigate the role of fauna underpasses in providing connectivity between quenda (*I. obesulus* ssp. *fusciventer*) populations impacted by main road construction.
- In collaboration with Mark Eldridge (Australian Museum), assess the genetic diversity and genetic structure of extant populations of black-flanked rock wallaby (*Petrogale lateralis* ssp. *lateralis*) to inform future conservation management, including translocations.
- Use of DNA barcoding to confirm species identifications.

Progress

- DNA sequencing of *I. obesulus*, *I. auratus*, *I. macrourus* and their subspecies using mitochondrial and nuclear markers for taxonomic analysis has been undertaken. Preliminary analyses suggest further nuclear sequencing markers are needed to fully resolve species boundaries but that revision of *I. obesulus* sub-species designations is likely to be required.
- DNA analysis of quenda populations has been completed and population genetic analyses are currently being undertaken. Population viability analyses have been completed exploring the long-term trajectory of urban populations with and without fauna underpasses, and with an additional range of threats (fire, urban expansion).
- DNA analysis of rock wallaby populations has been completed and preliminary data analysis has investigated genetic diversity and structure of wheatbelt and northern WA populations.
- DNA barcoding was used to identify a stranded whale carcass as Omura's whale, constituting a new record for the species in WA

Management implications

- Resolution of taxonomic boundaries between *I. obesulus* and *I. auratus* and their broader relationships with eastern states bandicoots should enable revision of current threatened species status at state and commonwealth levels.
- Genetic and population viability analysis showed that quenda populations in small, isolated patches of remnant vegetation in the urban matrix are vulnerable to genetic erosion, inbreeding and population decline, particularly when connectivity within (fauna underpasses) or between (increased urbanisation) habitat patches becomes inhibited. The impact of fauna underpasses on population persistence is somewhat context-specific, but extinction risks are predicted to increase in the study populations without fauna underpasses.
- Genetic information on rock wallaby populations will enable a stocktake of the current status of nearly all extant populations, including the assessment of the effectiveness of past management interventions, and will contribute to planning of future conservation actions, including translocations.
- The presence of the rare Omura's whale in Australian waters adds to our knowledge of the distribution of this species and has been updated on the state's fauna list.

Future directions

- Investigate potential of other nuclear markers for taxonomic analysis of bandicoots to further resolve species classifications. Investigate use of coalescent models to infer the evolutionary history of the genus.
- Complete analysis of population genetics and gene flow in urban quenda populations, including parentage assignment of individuals using fauna underpasses.
- Comparison of historic and contemporary population genetics of rock wallaby wheatbelt populations to monitor genetic change and investigate impact of past management actions. Develop population viability analyses to predict future trajectory of threatened populations.

SP 2012-033 Genetic approaches for evaluating the contribution of the reserve system to fauna conservation

Team

K Ottewell, M Byrne, K Morris, D Coates

Context

Human-mediated landscape disturbance can affect the amount of genetic diversity present in populations of threatened species and their distribution across the landscape. One challenge facing conservation managers is understanding how management tools can be used to protect and facilitate genetic patterns and processes. For example, reserve design principles (comprehensiveness, adequacy, representativeness; single large or several small) can be just as well applied to conserve genetic diversity as species diversity.

Aims

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

Progress

- Quenda tissue samples have been sourced from Parks and Wildlife, UWA, Murdoch University and environmental consultants that cover the Swan coastal plain and Perth Hills. DNA extraction and genotyping of quenda samples is complete and awaiting further statistical analysis.
- Tissue samples have been sourced and DNA extractions are nearing completion for three target small mammal species in the Pilbara. Trials of microsatellite loci have been undertaken ready for genotyping of samples.

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

- 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. Assess genetic diversity patterns of quenda populations in continuous versus fragmented habitat.
- Complete microsatellite and mtDNA sequencing of Pilbara small mammal species. Analyse patterns of historical and contemporary population structure and genetic diversity and correlate with environmental and landscape features. Investigate development of niche-based species distribution models for each species (past and present) and correlate with genetic data.
- Perform meta-analysis of Pilbara vertebrate genetic datasets to identify genetic diversity 'hotspots' and concordance in population structure among species.

SP 2012-025 Barrow Island Threatened and Priority fauna species translocation program

Team

K Morris, N Thomas, AH Burbidge, J Angus, S Garretson

Context

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

Aims

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

Progress

- All translocated mammal (other than earlier failure of brushtail possums at Cape Range) and bird species are well established at their respective translocation sites.
- Translocated mammals are maintaining good body/reproductive condition.
- Ongoing monitoring program of translocated species at their respective locations with the monitoring of mammals on the Montebello Islands reduced to biennially.
- A constrained randomised camera trap array has been established on Hermite Island to monitoring spectacled hare-wallabies. Initial results indicate that the hare-wallabies now occur throughout most of the island.
- No further translocations have occurred since 2012 due to lack of sites where feral cats and foxes are adequately under control.
- Taxonomic work on the water rat has shown that the Barrow Island form is sufficiently different from the south-west form to warrant subspecific status. This has implications for sourcing founder water rats for the proposed reintroduction to the Montebello Islands.
- Barrow Island fauna translocation strategy developed and workshop held to plan future translocations.
- Draft business case for an expanded fenced enclosure at Lorna Glen prepared.
- Annual report on progress provided to Chevron.
- Project advisory group continued to provide guidance.

Management implications

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

Future directions

- Implement Barrow island fauna translocation strategy.
- Develop future fauna translocation plan based on outcomes from March 2015 workshop.
- Research into effectiveness of feral cat baiting at Cape Range to be undertaken in 2016 so that an integrated fox/cat baiting regime can be developed for more effective reduction in fox and feral cat abundances. This will contribute significantly to this site becoming another fauna reconstruction site.
- Ongoing monitoring of the translocated mammals and birds at all the release sites.
- Continue to plan for an expanded fenced enclosure at Lorna Glen in the context of an Indigenous Protected Area agreement with traditional owners.

SP 2012-024 Rangelands restoration: reintroduction of native mammals to Lorna Glen (Matuwa)

Team

C Sims, K Morris, T Chapman, N Burrows

Context

Operation Rangelands Restoration commenced in 2000 with the acquisition of Lorna Glen and Earraheedy pastoral leases by the Western Australian Government. This 600,000 ha area lying across the Gascoyne and Murchison IBRA regions is now the site for an ecologically integrated project to restore ecosystem function and biodiversity in the rangelands. This is being undertaken in collaboration with the traditional owners. In 2014 Native Title (exclusive possession) was granted over Lorna Glen (Matuwa) and Earraheedy (Kurrara Kurrara). The area around Lorna Glen once supported a diverse mammal fauna that was representative of the rangelands and deserts to the north and east. These areas have suffered the largest mammal declines in Western Australia. This project seeks to reintroduce 11 arid zone mammal species following the successful control of feral cats and foxes, and contribute significantly to the long-term conservation of several threatened species. Mammal reconstruction in this area will also contribute significantly to the restoration of rangeland ecosystems through activities such as digging the soil and grazing/browsing of vegetation, and assist in the return of fire regimes that are more beneficial to the maintenance of biodiversity in the arid zone.

The first of the mammal reintroductions commenced in August 2007 with the release of bilby (*Macrotis lagotis*) and wayurta (*Trichosurus vulpecula*). Another nine species of mammal are proposed for reintroduction over the next ten years. Between 2010-2012, mala, Shark Bay mice, boodies and golden bandicoots were translocated into an 1100 ha introduced predator proof fenced enclosure. The intention is to use these as a source for translocations to areas of Lorna Glen outside the enclosure where cats have been effectively controlled, and ultimately the establishment of free-ranging self sustaining populations.

Aims

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

Progress

- Determination of Native Title to the Martu traditional owners over the Lorna Glen (Matuwa) property.
- Monitoring of mulgara populations inside and outside the enclosure.

- Widespread presence of bilbies across the bullimore sandplain land system and other habitats, and persistence of possums in core habitat.
- Monitoring of boodies and bandicoots inside the enclosure. Good population numbers and reproductive rates persist.
- Expansion of boodie presence and new warren systems within the fenced enclosure.
- Determination of home range of golden bandicoots within the enclosure.
- Eradicator baiting in 2014 only reduced cat abundance by 30-60% and wild dogs by ~ 25%, with remaining predator numbers deemed too high for successful translocations resulted in suspension of golden bandicoot release plans.
- Effects of bilby, boodie and varanid digging activity on soils and plants examined.
- A study of a boodie warren showed that soils on the warren were up to 100 times higher in plant limiting nitrogen than soils off the warren. Cotton bush (*Ptilotus obovatus*) growing on the warren had significantly more living tissue, greater leaf biomass and larger leaves.
- Experiments showed that boodies move sandalwood (*Santalum spicatum*) seed away from the parent plant and cache or bury the seed near potential host plants, which is one of the primary means of promoting sandalwood recruitment.
- Ongoing study of wedge tailed eagle ecology, reproduction and movement patterns, including satellite telemetry of 2 adult and 2 fledgling birds.
- Study into importance of bilby burrows as refuges for other vertebrate fauna.

Management implications

- Fauna reconstruction and monitoring techniques for arid zone rangelands developed by this project will have broad state and national application for the conservation of threatened fauna.
- The outcomes of the project will contribute to the management of Parks and Wildlife's rangeland properties and provide guidance for future fauna reconstruction, e.g. Dirk Hartog Island. It will also demonstrate effective partnership models with traditional owners and facilitate collaborative management with traditional owners.

Future directions

- Development of future engagement and cooperation with traditional owners in some management and monitoring activities.
- Ongoing monitoring of bilbies and possums outside the enclosure, and of bandicoots, boodies, mala and Shark Bay mice inside the enclosure.
- Develop plans for reintroductions of red tailed phascogales in 2016.
- Investigate the genetic health of possum population and assess need for future genetic supplementation.
- Undertake release of golden bandicoots in 2015, including additional feral control activities if aerial bait in 2015 fails to reduce feral cat numbers sufficiently on its own.
- Develop strategies for releases of boodies and bandicoots outside the enclosure in the presence of low densities of feral cats.
- Investigate the influence of reintroduced mammals on soils and plants and their potential to facilitate restoration.
- Commence planning and traditional owner liaison for expansion of fenced enclosure to 5,000 ha.

SP 2012-023 Feral cat control and numbat recovery in Dryandra woodland and other sites

Team

A Friend

Context

Dryandra Woodland supports important populations of several threatened mammals, including the numbat, woylie and red-tailed phascogale, as well as significant populations of a number of threatened birds. Recent research has shown that feral cats are responsible for the majority of numbat and woylie deaths. This project investigates the feasibility and efficacy of using the *Eradicat* feral cat bait to reduce numbat and woylie mortality and promote their recovery at Dryandra.

Aims

1. To determine the uptake of rhodamine-labelled non-toxic *Eradicat* baits by chuditch, red-tailed phascogales and mardos in Dryandra.
2. To determine the survival or mortality of groups of radio-collared chuditch, red-tailed phascogales and mardos during a baiting campaign using toxic *Eradicat* baits in Dryandra.
3. To determine the survival or mortality of feral cats through a baiting campaign using toxic *Eradicat* baits in Dryandra.

Progress

- Ten feral cats were fitted with GPS collars between October 2014 and March 2015. A cat baiting campaign was planned for mid-March 2015.
- Eight chuditch were fitted with radio-collars between January and March 2015.
- Failure of seven of the cat collars prior to the baiting event reduced the number of collared cats exposed to cat baiting to three. Collar failure was a manufacturers error.
- No cats died in the baiting event, perhaps because all of these cats were resident in farmland adjacent to Dryandra, rather than in the Woodland itself.
- All chuditch survived the *Eradicat* baiting.

Management implications

On the basis of the results of this and previous years' results, *Eradicat* can most likely be used with minimal non-target impact in Dryandra Woodland. This is significant for the implementation of integrated fox and feral cat control programs at Dryandra and elsewhere in the south-west of WA.

Future directions

- Repeat the *Eradicat* trial with GPS collared cats in Dryandra Woodland in 2015-16 to determine the effectiveness of this control method.
- Monitor cat density before and after baiting using remote sensor cameras.
- Integrate this work into the proposed south-west fauna recovery project due to commence in January 2016.

SP 2012-022 Conservation of south coast threatened birds

Team

AH Burbidge

Context

Identifying the conservation requirements of threatened south coast birds such as the Critically Endangered western ground parrot, the Vulnerable western bristlebird and the western subspecies of the western whipbird

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

Aims

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

Progress

- Continued integrated predator management on the south coast in an adaptive management framework, including monitoring ground parrots in Fitzgerald River National Park and before and after baiting for cats in Cape Arid National Park. The monitoring protocols are being refined through use of audio recordings.
- Carried out further genetic analysis of western whipbird phylogeny; outcomes being incorporated into formal conservation status listing.
- In collaboration with South Coast Region, assisted in transfer of captive birds to Perth Zoo, and progressed development of protocols for captive breeding.
- Assisted in obtaining better quality reference calls to facilitate monitoring through scanning of field recordings for ground parrot calls

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

- Finalise writing up of data on response to fire by bristlebirds and write up data on morphometrics of the western ground parrot.
- Implement further field-scale feral cat control (with monitoring) in key ground parrot habitat (with South Coast Region).
- Capture more individuals for the captive breeding program (if resources are available) and continue to develop captive breeding protocols.
- Continue work on genetic relatedness of populations of whipbirds, to provide a whole of taxon overview of taxonomic and conservation status.
- Continue to develop monitoring analyses and techniques.

SP 2011-005 Ecology and management of the northern quoll in the Pilbara

Team

J Dunlop, K Rayner

Context

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

Aims

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

Progress

- Northern quoll monitoring protocols developed, and subsequently approved by the Commonwealth.
- Ten regional monitoring sites selected and the first season of regional monitoring completed in November 2014.
- The second season of regional monitoring commenced in May 2015.
- Collaboration with Edith Cowan University to model suitable quoll habitat in the Pilbara commenced.
- Northern quoll workshop proceedings finalised for publication in *Conservation Science WA*.
- Quoll distributional data added to the Pilbara Threatened Species portal in NatureMap.
- Trialled the use of GPS radio-collars on northern quolls for the first time.
- Extensive liaison with Roy Hill regarding ongoing quoll monitoring and research on and near their mining leases.

Management implications

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

Future directions

- The second season of regional monitoring will be completed in November 2015, and the third monitoring season will commence in May 2016.
- Habitat modelling project will be completed by May 2016.
- Continue to collect tissue for population genetic analyses (Murdoch University).
- Develop research proposals that examine the impact of mining infrastructure such as roads and railways on quoll movements and survivorship.

SP 2010-006 Conservation of the graceful sun-moth

Team

M Williams, A Williams

Context

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

Aims

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

Progress

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

Management implications

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

Future directions

- 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.

SP 2007-002 Identifying the cause(s) of the recent declines of woylies in south-west Western Australia

Team

A Wayne, C Ward, C Vellios, M Maxwell

Context

Following a major population recovery following fox control in the 1990s, 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 conservation status of woylie has been upgraded to Critically Endangered as a result.

Aims

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

Progress

- A WWF funded project in collaboration with James Cook University has been conducting an outbreak investigation for the woylie. The project began in 2013 and is currently preparing a scientific paper for submission in 2015. A PhD project is being secured to continue the work beyond this.
- An ARC linkage project 'The Ecology of Parasite Transmission in Fauna Translocations' commenced in 2013 and Parks and Wildlife is an industry partner in this, contributing to the project design and providing assistance in the field. The translocation of 182 woylies from Perup Sanctuary to two sites in Greater Kingston was completed in June 2013. Pre and post translocation monitoring is providing evidence of the effects of these conservation actions on the populations of woylies and sympatric mammals at the source and destination sites. A similar process is now also underway for a third translocation of 69 woylies from sites across the Upper Warren to Dryandra (the other remaining natural woylie population) conducted in June 2014.
- Other monitoring of woylie populations and introduced predators within the Upper Warren region as part of this project have ceased. Some monitoring continues as part of Western Shield and district programs, to which this project has continued to provide practical support.
- The evidence remains consistent in indicating that the woylie declines have been mortality-driven, principally due to the predation (particularly by cats) of individuals that may have become increasingly vulnerable due to disease.
- Collaborative disease investigations continue, particularly into the key associations with the declines.
- Seven native species have now successively declined since 1994 in the Upper Warren region (dunnart, wambenger, bush rat, quenda, ngwayir (western ringtail possum), woylie and western brush wallaby), to similar extents (>80%), at similar rates and with no signs of significant or sustained recovery. The chuditch, koomal (brushtail possum) and tammar wallaby have more recently increased in the region.
- Several papers have been recently published in scientific journals and others are in preparation.

Management implications

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

Future directions

- Continued in kind support to the ARC linkage and WWF funded projects, Western Shield and district monitoring activities and the students associated with this project.
- Participate in the development of an effective, integrated fox and feral cat baiting program that results in the recovery of woylie and other threatened fauna populations.
- Analysis and publication in scientific journals of the research conducted to date

SP 2006-004 Impact of cane toads on biodiversity in the Kimberley

Team

D Pearson

Context

Cane toads constitute a serious threat to the biodiversity of the Kimberley and yet little robust data are available to assess their impacts. An ARC-linkage project with the University of Sydney and Parks and Wildlife as the major partners identified taxa most at risk from the toad invasion. Research now focuses on potential techniques to reduce the impact of cane toads on the most susceptible native predators in the Kimberley. In particular, taste aversion training is being investigated to mitigate the impact of cane toads on wild northern quoll and goannas (with Uni of Sydney researchers).

Aims

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

Progress

- Trials of a taste aversion sausage have been undertaken and results suggest that short-term learning is possible so that there is increased survivorship of “trained” individuals. Longer term training is currently being investigated at two sites, one in the East Kimberley and the other in the North Kimberley.
- In conjunction with the University of Sydney (Prof Rick Shine and PhD student Georgia Ward-Fear) and the Balanggarra rangers, we have trialled ‘teacher toads’, whereby wild goannas are challenged with small toads to teach them not to eat large invading toads which are typically lethal.
- I have provided input into considerations of the feasibility of a toad barrier near Broome relying on restricting access to water.
- Worked with regional staff to survey for toads and native predators on Adolphus Island.
- Published papers on behavioural responses of reptile predators and native rodents to invasive cane toads in *Austral Ecology* and the *Journal of Pest Science*.

Management implications

- This project has identified which native species are most at risk from cane toads and has examined a technique that may reduce the risk to toad-susceptible species.
- Taste aversion training using toad sausages laced with a nausea-inducing chemical or “teacher toads” (small dead toads with insufficient toxin to cause death) has been shown to be a potential management option to reduce consumption of cane toads by native fauna, including northern quolls and goannas. This is likely to be most useful to protect island populations of susceptible species or those in high value conservation sites on the mainland.

Future directions

- Continuation of landscape scale 'teacher' toad trials with floodplain goannas in conjunction with the Kimberley regional staff, Ballangarra Rangers and the University of Sydney.
- Quolls surveys on Adolphus Island to ascertain whether quolls persist and develop taste aversion in the absence of taste aversion baits.
- Trials with taste aversion baits at a mainland site (perhaps in the north Kimberley) to see whether this technique has value to reduce the impacts of cane toads on northern quolls.

SP 2003-005 Development of effective broad-scale aerial baiting strategies for the control of feral cats

Team

D Algar, N Hamilton

Context

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

Aims

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

Progress

- Research into bait composition is continuing with the objective of further improving bait uptake. Chemical synthesis of several compounds that elicit a chewing response by cats has been achieved. One of these compounds is being manufactured at a scale that will enable incorporation into baits and reliable assessment of any improvement to bait uptake. In addition, the surface coating of baits with mould inhibitors is continuing.
- Feral cat baiting programs on the Fortescue Marsh (Pilbara) were conducted in 2012, 2013 and 2014. All campaigns resulted in statistically significant declines in cat occupancy rates in the baiting area. A further baiting program is being conducted this winter. Research into the effectiveness of baiting strategies is continuing to be assessed under the temperate climatic conditions of the south-west at sites including Cape Arid and Fitzgerald River National Parks. The baiting programs conducted to date at Cape Arid National Park have contributed to an apparent stabilisation in the critically endangered western ground parrot population and significant population increases in number of other species, including the southern brown bandicoot. Similar results have been achieved at Fitzgerald River National Park where anecdotal increases in a number of native bird and mammal species have been observed.

- Stage 1 of the management plan for the control of cats on the tropical Christmas Island has been completed with all domestic cats having been desexed, microchipped and registered. Stage 2 of the plan is continuing and involves the removal of all stray/feral cats from the residential area and surrounds. Stage 3 of the plan - island-wide eradication of feral cats commenced in 2015 following the funding being secured to see the project to its conclusion.
- An assessment of bait consumption by the northern quoll is to be undertaken later this year. The bait medium will contain an encapsulated 1080 toxin. If the encapsulated toxin is demonstrated to be reliably rejected by quolls it will pave the way for feral cat campaigns to be conducted in northern Australia.
- Work has been completed on the lure for the active camera traps. A combination of olfactory and visual attractants are used and have been shown to be successful in attracting cats to the camera traps across temperate, semi-arid and tropical environments. Also, a new audio lure is currently being tested as a further trap attractant.

Management implications

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

Future directions

- Continue refinement of bait medium to improve bait consumption by feral cats.
- Analyse baiting effectiveness at the various research sites and refine the method of operation where necessary to optimise baiting efficacy.
- Further investigation of bait consumption by non-target species and devise methods to minimise risk (eg. toxin encapsulation).
- Provide a standard operating procedure for camera trap lures for feral cats.

SP 1996-008 Gilbert's potoroo (*Potorous gilbertii*) recovery plan

Team

A Friend, S Hill, T Button

Context

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

Aims

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

Progress

- A census of the Mount Gardner population (Two Peoples Bay NR) of Gilbert's potoroos is conducted three times a year. Numbers remained stable from 2001 when this regime was introduced, until November 2013, when a significant decline was detected. Eight potoroos, representing about 75% of the Mt Gardner population were known to be alive in March 2015.
- During 2005-2007, ten potoroos were transferred from Two Peoples Bay to Bald Island. Trapping between three and six times per year showed that the translocated population grew rapidly. Between 40 and 50 potoroos are known to be alive on the island, despite the removal of a total of 42 individuals since 2008 for translocations to the mainland. The majority (36) were transferred to the 380 hectare enclosure at Norman's Beach, Waychinicup National Park. The other six animals were released outside the fence into a fox-baited area.
- Monitoring of the population in the Waychinicup enclosure by trapping, radio-tracking and motion-activated cameras has shown that some of the potoroos use vegetation types floristically and structurally different to that occupied at Two Peoples Bay, and that breeding and recruitment are occurring. Carpet pythons were found to be significant predators of potoroos at Two Peoples Bay and Waychinicup.
- In March 2015, 13 potoroos were known to be alive in the enclosure, of which nine were born on-site.

Management implications

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

Future directions

- Continue to monitor the Mount Gardner, Bald Island and Waychinicup National Park (enclosure) populations, by trapping and radio-tracking. Continue to monitor the enclosure for incursion by cats or foxes. Implement structured trapping to determine habitat use.
- Evaluate further translocation sites, both on the mainland and on other islands.
- An updated draft of the Gilbert's Potoroo Recovery Plan will be produced and circulated for comment in 2015-16.

Plant Science and Herbarium

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

by Australia's and the world's scientific community; providing authoritative information to government, industry and the community via the FloraBase website and the Herbarium's information management systems.

SP 2013-052 Interactive key and taxonomic studies of Myrtaceae tribe Chamelaucieae

Team

B Rye

Context

Taxonomic revision is required in various plant groups to facilitate appropriate determination of their conservation status. The main group of plants under study, Myrtaceae tribe Chamelaucieae, comprises over 800 species of shrubs, including over 200 unnamed species and subspecies. The lack of an adequate taxonomy continues to impede their conservation, study (in fields other than taxonomy) and commercial utilisation. 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 tribe Chamelaucieae of the Myrtaceae.
- Produce and continually update an interactive key to members of this tribe.

Progress

- Papers on *Astartea*, *Ericomyrtus* and *Thryptomene* (Myrtaceae: Chamelaucieae) were published in *Nuytsia*.
- Papers on *Babingtonia* and *Hysterobaeckea* (Myrtaceae), *Isopogon* (Proteaceae) and five new species of Cyperaceae have been submitted.
- Several other papers are in preparation and an interactive key to Myrtaceae tribe Chamelaucieae has been continually updated.

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

- Official release of the interactive key through publication of an introductory paper in *Nuytsia*. Hold a workshop to demonstrate the key.
 - Submit papers on *Hypocalymma* and a new subgeneric classification (Myrtaceae).
 - Seek involvement with eFlora of Western Australia project.
-

SP 2012-031 Biosystematics of fungi for conservation and restoration of Western Australia's biota

Team

N Bougher

Context

This project represents a 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.

Progress

- Completed and submitted monographic book manuscript for the Fungi of Australia series entitled Fungi of Australia: Inocybaceae
- Revised the names of 450 fungi species aligning them with ALA/AusFungi for inclusion in WACensus

Management implications

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

Future directions

- Review, editorial and publication processes for monographic book on the Australian Inocybaceae.
- Taxonomic research defining and documenting species of fungi in WA.
- Improve representation and accuracy of data for fungi in the WA Herbarium and in WACensus.
- Fungi surveys in bushlands in conjunction with public community members.

SP 2012-021 Climate change risks for biodiversity and ecosystem function in species-rich shrublands

Team

C Yates

Context

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

Aims

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

Progress

- Continue to write up results from climate manipulation experiments and prepare manuscripts for publication

Management implications

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

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

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

Future directions

- Publish results from climate manipulation experiments in scientific journals.

SP 2012-006 Strategic taxonomic studies in families including Amaranthaceae and Fabaceae (*Ptilotus*, *Gomphrena*, *Swainsona*) and other plant groups

Team

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.

Progress

- Paper on a molecular study of *Ptilotus* has been published in botanical journal Taxon.
- Two new species of *Ptilotus* from the Eneabba region were discovered and paper published.
- A short communication to synonymise priority taxon *Hibiscus* sp Ninghan Station has been 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

- 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*.
- Finalise paper dealing with the synonymy of *Adenanthos pungens*.
- Prepare paper on a new species of *Nymphoides* from the Gascoyne.

CF 2011-111 The Western Australian Plant Census and Australian Plant Census

Team

C Parker, J Percy-Bower, T Macfarlane

Context

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

The Australian Plant Census (APC) is a project of the Council of Heads of Australasian Herbaria, designed to provide a consensus view of all Australian plant taxa. Until now plant censuses have been only state-based, which has made it difficult to obtain authoritative information on what species occur in Australia as a whole, to obtain accurate national statistics, and to deal with differences in opinion and knowledge for taxa that cross state boundaries. In addition to working systematically through the vascular plant families, the APC process provides for updates as taxonomic changes or new findings are published. The consensus also extends from family and genus level to an overall classification of the plants that occur in Australia. As the APC project continues, the Western Australian Plant Census is updated to reflect the consensus view.

Aims

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

Progress

- 301 plant names were added to the plant census, comprising 283 names formally published and 18 informal names and 773 other edits were made to the census.
- WACensus updates were regularly distributed to 257 registered Max users.
- The last major family processed for the APC (Orchidaceae) was progressed and is still ongoing.
- An APC update list is being finalised covering latest changes to a number of taxa in families including; Asteraceae, Cyperaceae, Euphorbiaceae, Fabaceae, Hypoxidaceae, Lamiaceae, Liderniaceae, Myrtaceae and Phrymaceae.

Management implications

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

Future directions

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

CF 2011-110 The Western Australian Herbarium's specimen database

Team

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

Context

The Western Australian Herbarium's specimen database (WAHerb) allows staff at the Herbarium to manage and maintain the Herbarium's collections, and provides core data on the distribution, ecology and morphology

of all taxa for Parks and Wildlife and the community, through the FloraBase and NatureMap websites. Data from the specimen database is provided to researchers, consultants and community members on request, and to the Australian Virtual Herbarium (AVH), Atlas of Living Australia (ALA) and the Global Biodiversity Information Facility (GBIF) on a regular basis.

Aims

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

Progress

- 8732 records were added to the specimen database, including 961 Priority Flora and 211 Threatened Flora. The following projects and significant collections were databased: Herbarium staff and research associates, surveys by industry consultants, Parks and Wildlife surveys (Yilgarn Ranges Survey, Woylie Decline Project), Inocybaceae research by N. Bougher and general fungi collections.
- Regularly provided customised specimen data requests (species lists and label data) to Parks and Wildlife officers, researchers and the public.
- 727368 specimen records were edited during this period as part of activities aimed at ensuring the collection is scientifically valid, up-to-date and aligned with the Departments conservation codes.

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

Timely editing and validation of herbarium specimen records to maintain connectivity between the Herbarium collection, the Western Australian Plant Census and external databases including AVH and ALA.

CF 2011-105 Herbarium collections management

Team

K Knight, C Parker, K Thiele, J Percy-Bower, R Rees, S Coffey, M Falconer, E McGough, R Davis, M Hislop

Context

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

Aims

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

- Contribute to, support and service taxonomic research by the world's scientific community.

Progress

- 8732 specimens were added to the collection, which now stands at 759797, a 1.16% increase in holdings during this period.
- The major plant groups in the collection are summarised in Appendix 1, Table 1
- Loans and exchange: loans outward—18 loans consisting of 484 specimens; loans inward—7 loans consisting of 115 specimens; loans returned to the Herbarium—28 loans consisting of 713 specimens; loans returned to their home institution—24 loans consisting of 515 specimens; exchange inward—1137 specimens; exchange outward—1222 specimens including 12 requests for destructive sampling.
- Volunteer participation was significant, totalling 8993 hours which is equivalent to 5 full time employees.
- Tasks managed by Collections staff with the assistance of volunteers were as follows: mounting and labelling 8441 specimens; validating the name and occurrence of 2327 incoming specimens for lodgement.
- Recruited 45 volunteers.
- Reference Herbarium: maintained the facility, which has over 14775 specimens representing 11702 taxa and also added or replaced 180 specimens. 1108 visitors used this resource to identify plant specimens during this period. This year the Swan River Trust Reference Collection was merged with the Reference Herbarium.
- Research Collection: accessed by 432 visitors to study taxa or help identify specimens.
- Provided 94 high resolution scans of herbarium specimens to Parks and Wildlife district staff and industry consultants to aid in the identification and location of known and new populations of priority and threatened taxa.
- Significant lodgements: industry surveys, regional DPAW officers, DPAW Kimberley Islands survey, R. Chinnock (cactus), M. & R. Barrett, Desert Discovery, N. Gibson (*Calothamnus* study).
- Reviewed, documented and made available on the Herbarium webpage: destructive sampling policy, exchange policy, loans policy, loans conditions and quarantine guidelines.
- The Herbarium Identification Program provided identifications to a range of clients and specialises in taxa and specimens that clients find challenging. Our most significant clients included Parks and Wildlife, other government agencies, environmental consultancies, regional herbaria and the public.
- Educational role: provided tours of the Herbarium for tertiary institutions, Parks and Wildlife staff, environmental consultancies and community groups.
- Scanned 532 types for the Global Plants Initiative. The project was completed this year; 7857 WA Herbarium type specimens are now accessible to the world's scientific community and other botanical resources for study.

Management implications

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

Future directions

- Continue to maintain the collection to an authoritative standard for all users.
- Continue to review and document collections management policy and procedures to effect efficiencies and reflect modern herbarium practices, and where applicable make available on the Herbarium webpage.
- Recruit and retain 50 new volunteers to assist in key Herbarium functions.

CF 2011-104 Biodiversity informatics at the Western Australian Herbarium

Team

K Thiele, B Richardson

Context

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

Aims

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

Progress

- Made FloraBase display effectively on smartphone and (small) tablets
- Improved FloraBase security features to make it less susceptible to spam
- Completed a major revision of the management of user accounts, to avoid a dependence on old and deprecated software that can no longer be supported.
- Fixed searching, display and editing issues.
- Progressed development of a Specimen Accessioning Tool to a late draft stage; this will allow users of FloraBase to determine whether specimens should be sent to the Herbarium for incorporation into the collection.
- Continued updating FloraBase's presentation of images, using images from ImageBank.

Management implications

- FloraBase allows the community and Department staff to retrieve the most recent information on the name, features, status and distribution of the 13708 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

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

SP 2011-015 Taxonomy of undescribed taxa in the Ericaceae subfamily Styphelioideae, with an emphasis on those of conservation concern

Team

M Hislop, A Chapman, K Thiele

Context

Epacrid classification is undergoing fundamental reassessment at the generic level as new information on relationships is revealed. *Leucopogon*, in particular, is species-rich in Western Australia but is relatively poorly understood and includes many undescribed taxa, including ones of conservation significance. It is also clear that the genus cannot be maintained in its current circumscription, although generic boundaries are still uncertain. This project will continue to describe new taxa in *Leucopogon*, *Melichrus* and other genera in the subfamily Styphelioideae and, in collaboration with partners in eastern Australia, work towards a generic reclassification of the subfamily.

Aims

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

Progress

- A paper describing a new and geographically restricted species of white-flowered *Brachyloma* published in *Nuytsia*.
- A paper accepted by *Nuytsia* in which a new and probably rare species of *Leucopogon* s. str. from the south-west corner of the state is described.
- A draft paper with descriptions of 5 new species of *Leucopogon* s. str. from the Geraldton Sandplains is well-advanced.
- A draft paper with descriptions of 5 new species of *Styphelia* (currently in *Leucopogon* s. lat.) from the Geraldton Sandplains is progressing.
- A collaborative paper with researchers in eastern Australia and USA has been conditionally accepted by *Australian Systematic Botany*. This paper lays the foundations for a greatly expanded *Styphelia* which will encompass all elements of *Leucopogon* not belonging to *Leucopogon* s. str. as well as *Astroloma*, *Croninia* and *Coleanthera*.
- Collaboration with regional Flora Officers on the nominations of two epacrid species for Threatened Flora status: *Leucopogon* sp. Ongerup and *Leucopogon nitidus*. Both have now been assessed as Threatened Flora.

Management implications

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

Future directions

- Preparation of further papers describing new taxa in *Leucopogon*, *Brachyloma* and *Styphelia*.
- Further field studies to assist in the resolution of *Styphelia* sensu lat.

SP 2011-014 Strategic taxonomic studies in families including Epacridaceae, Rafflesiaceae, Rhamnaceae and Dilleniaceae

Team

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.

Progress

- A paper describing *Hibbertia robur*, a new species formerly known as *H. sp.* Mt Adams, has been published in *Nuytsia*.
- A paper establishing for the first time the evolutionary relationships in the mulla mulla genus *Ptilotus*, co-authored with a student Tim Hammer, has been published in the international journal *Taxon*
- Herbarium studies have led to the resolution of further new species in *Hibbertia*. Three of these, all segregates from the Priority 3 species *Hibbertia argentea*, are all rare and localised, one currently known only from a single specimen and likely to be Threatened. Another new taxon, phrase-named as *H. sp.* Mount Gibson, is also quite restricted and rare and has been listed as Priority 3.

Management implications

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

Future directions

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. Three species groups in the genus (the *H. exasperata*, *H. lineata*, and *H. hypericoides* species groups) are under active taxonomic review and are yielding new species.

SP 2011-013 Taxonomic studies on native and naturalised plants of Western Australia arising from biological survey

Team

G Keighery

Context

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

Aims

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

Progress

- Attended led sessions on prioritisation and presented at Kimberley weed Workshop and produced new weed checklist for Kimberley.
- Workshops on prioritisation of localised, widespread and alert weeds undertaken in all nine Parks and Wildlife regions and districts.
- Several new weeds recorded for Western Australia.
- Papers on adding deleting weeds for WA prepared.
- Paper on weeds on southern offshore islands published.
- Papers on weedy *Banksia* species, status of *Typha orientalis*, and on *Heliophila* in Western Australia published.
- A new species of *Angianthus* published. Two new species of *Tricoryne* published.

Management implications

- *Typha orientalis* a weedy native not introduced alien.
- 21 weeds to be deleted from WA census.
- Comments on status of 24 weeds made.

Future directions

- Continue updating the curation, nomenclature and status of naturalised vascular plants for Western Australia by preparing briefing notes, reports and short articles and papers as issues arise
- Publish paper on system for adding and deleting naturalised plants to the flora of Western Australia
- Publish paper on weeds of West Coast islands
- Assist the C.E.B.R.A. Independent review of Barrow Island Surveillance system as an invited expert
- Complete drafting descriptions of 25 new *Darwinia* species
- Submit paper on *Hypocalymma angustifolium* complex

SP 2011-002 Resolving the systematics and taxonomy of *Tephrosia* in Western Australia

Team

R Butcher

Context

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

Aims

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

Progress

- A paper providing a conspectus of *Tephrosia* in the Eremaean Botanical Province, including descriptions for 15 to 20 undescribed taxa, is in preparation.
- All *Tephrosia* specimens submitted to the Western Australian Herbarium by external stakeholders were examined and had their identifications confirmed or corrected, thus maintaining the accuracy of *FloraBase*.
- All *Tephrosia* specimens in the Reference Herbarium had their quality assessed and identifications reviewed in light of taxonomic changes, and all taxa for which there is sufficient material are again represented.

Management implications

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

Future directions

- 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.
- Publish taxonomic papers describing new species endemic to Western Australia's Northern Botanical Province (Kimberley region).
- Collaborate with specialists in the Northern Territory and Queensland to resolve and describe new taxa occurring across Australia's monsoon tropics.

SP 2011-001 Taxonomy of selected families including legumes, grasses and lilies

Team

T Macfarlane

Context

Successful conservation of the flora requires that the conservation units equate to properly defined, described and named taxa. There are numerous known and suspected unnamed taxa in the grass, legume and lily 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.

Progress

- *Wurmbea* (Colchicaceae): continued field work to assess conservation status of poorly known species and obtain photos. Progress continued on writing paper to describe thirty new species.
- Hydatellaceae: paper submitted on phylogeography of *Trithuria submersa*; second season of field work for population genetic component of interim recovery plan for critically endangered species *T. occidentalis*, and samples of all south western species obtained for Vancouver-based phylogenetic study.
- Poaceae: further field work and research collaboration on *Neurachne* and the evolution of C4 photosynthesis, involving expanding a living collection of species and locating known and new populations of *N. lanigera* and *N. munroi*.
- *Thysanotus* (Asparagaceae): Paper describing two new species continued with identification of additional populations. Grant obtained to review the taxonomy of the twining species, the *T. patersonii* group.
- *Lomandra* (Asparagaceae): paper describing the new species *L. marginata* published.
- *Tricoryne* (Asparagaceae): paper describing the two new species *T. tuberosa* and *T. soullierae* published.
- *Logania* (Loganiaceae): a review of variation in *L. serpyllifolia* required further study. Draft paper not progressed.
- Haemodoraceae: paper describing seven new Kimberley species is in press.
- Asparagales: paper on a neglected taxonomically useful flower feature in several plant families is in press.

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

- Complete and submit papers describing new species of *Wurmbea*, *Thysanotus* and *Lomandra*. Conduct field searches for 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. Current targets are new species of *Rytidosperma* (Poaceae) and reviews of *Arthropodium* and *Lepilaena* in WA.
- Publish information on selected plant groups for general audiences. Articles are currently planned for *Wurmbea* and *Thysanotus*.

SP 2010-003 Temperature thresholds for recruitment in south-west Western Australian flora

Team

A Cochrane

Context

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

Aims

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

Progress

- Paper published in *Plant Ecology* describing effects of experimental treatments on seedling performance in four *Banksia* species.
- Paper published in *Australian Journal of Botany* detailing the effects of artificially induced moisture stress and temperature on germination in populations of four *Banksia* species.
- Continuing assessment of the temperature niche for germination in species from the South West.

Management implications

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

Future directions

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

SP 2010-001 Systematics of the triggerplant genus *Stylidium*

Team

J Wege

Context

With almost 300 known taxa, the triggerplant genus *Stylidium* is one of the most abundant and diversified genera in Australia. While substantial progress has been made over the past 20 years in documenting Australia's *Stylidium* diversity, our knowledge of the genus remains insufficient for scientific and conservation needs. There are 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 84 taxa are conservation-listed, the majority of which require further survey to understand the full extent of their distribution.

Aims

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

Progress

- A taxonomic revision of the *S. junceum* alliance was published in *Nuytsia*. A further two taxonomic papers were submitted for publication.
- Survey of the rare and potentially threatened species *S. hygrophilum* was conducted and seed was banked with the Threatened Flora Seed Centre (in collaboration with Andrew Webb and Ben Lullfitz: South West Region).
- A Threatened flora nomination for *S. coroniforme* subsp. *amblyphyllum* was prepared and submitted (in collaboration with Natasha Moore: Wheatbelt Region, Merredin).
- Baseline data and collections relevant to future taxonomic papers were obtained during the spring field season, at which time new populations of poorly known species were discovered and novel pollination observations were made.
- Progress on an interactive key to *Stylidium* was made.

Management implications

- Taxonomic research and targeted field work has improved our understanding of the distribution, habitat requirements and conservation status of a range of triggerplant species.
- An interactive key to *Stylidium* will greatly improve the speed and accuracy of identifications by industry, government and the general public, facilitating their conservation and management.

Future directions

- Progress interactive key and phylogenetic research.
- Prepare taxonomic papers on focus groups and conduct targeted field research as required.
- Prioritise and prepare threatened flora nominations and associated field survey.

SP 2009-009 Taxonomic review and floristic studies of the benthic marine algae of north-western Australian and floristic surveys of Western Australian marine benthic algae

Team

J Huisman, C Parker

Context

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

Aims

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

Progress

- The book *Algae of Australia: The Marine Benthic Flora of North-western Australia, 1. The Green and Brown Algae* has been published by ABRS and CSIRO Publishing. This book includes 68 genera and 171 species. Each taxonomic level, from division to species, is fully described, incorporating current nomenclature, morphology, keys and numerous illustrations, many in colour. It is the first detailed account of the marine plants of tropical Western Australia and documents numerous taxa recorded for the first time from the region, together with newly described species of *Avrainvillea*, *Codium*, *Sargassum* and *Ulva*. Most sections were authored by J.M.Huisman, some in collaboration with international and national experts.
- Continued generation of descriptions and illustrations for a second book in the series, *Algae of Australia: Marine Benthic Flora of North-western Australia, 2. The Red Algae*. The majority of the text and illustrations have been prepared and edited/formatted by Australian Biological Resources Study in readiness for submission in late 2015 and publication in early 2016. This book will include descriptions of several hundred species, over 50 of which are new to science.
- Participation in a field survey to the Rowley Shoals by collaborator Gareth Belton, and to Coral Bay by John Huisman, resulting in numerous new collections that will add several hundred specimens to the herbarium holdings. These collections include several new species of red algae that will be described in the abovementioned book.
- Several additional major papers and a chapter have been published concerning aspects of the north-western Australian marine flora, including a reassessment of the red algal order Nemaliales, an account of historical collections, and a survey of the Bonaparte Archipelago and Browse Basin.
- Publication of the first Western Australian record of the invasive green seaweed *Codium fragile* subsp. *fragile*, and the first confirmed record of the toxic dinoflagellate *Alexandrium catenella*

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

- Further surveys of the marine algae of remote Western Australian locations. In 2015 this has included Coral Bay, the Capes region of south-west Western Australia, and Nornalup Estuary. The latter has resulted in the first record of a South African estuarine green alga, *Codium tenue*, in Australia, representing a highly disjunct and unusual distribution.

- Publication of papers describing new and existing genera, species and other categories; contributions to FloraBase.
- Finalise production of *Algae of Australia: The Marine Benthic Flora of North-western Australia, 2. The Red Algae*, to be published by the Australian Biological Resources Study in 2016.

SP 2009-008 The Western Australian marine benthic algae online and an interactive key to the genera of Australian marine benthic algae

Team

J Huisman, C Parker

Context

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

Aims

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

Progress

- Numerous descriptions at all taxonomic levels have been prepared, as part of the recently published book *Algae of Australia: The Marine Benthic Flora of North-western Australia, 1. The Green and Brown Algae*. These will be uploaded to FloraBase.
- The second book in the series, *Algae of Australia: The Marine Benthic Flora of North-western Australia, 2. The Red Algae*, is nearing completion and will be published in 2016, at which time all new descriptions will be uploaded to FloraBase.
- Numerous additional *in situ* and microscopic images of marine algae have been taken. Over 50 new images have been uploaded to ImageBank.
- 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

- Continue preparation and finalize interactive key. As with FloraBase descriptions, this will be based substantially on the contents of the two books describing the north-western Australian algal flora.
- Continue collating existing species descriptions and write new descriptions for uploading to FloraBase.
- Upload additional marine plant images to ImageBank/FloraBase.

SP 2009-006 Taxonomic resolution and description of new plant species, particularly Priority Flora from those areas subject to mining in Western Australia

Team

J Wege, K Shepherd, M Hislop, R Butcher

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 1435 putatively new and undescribed taxa currently recorded 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.

Progress

- Papers describing eight new taxa in *Brachyloma*, *Daviesia*, *Gastrolobium*, *Spartothamnella* and *Stylidium* were published in *Nuytsia*.
- A morphometric study examining taxon boundaries in *Synaphea* was published in *Australian Systematic Botany*, the results of which support the formal description of four Threatened species from the Swan Coastal Plain.
- A paper summarising the achievements of this strategic taxonomy project was published in *Biodiversity and Conservation*.
- Papers resolving the taxonomy of *Atriplex* sp. Yeelirrie Station (L. Trotter & A. Douglas LCH 25025), a Threatened species from a mining lease, and three poorly known species of *Lasiopetalum* were submitted for publication.
- Approximately 350 *Tecticornia* specimens from industry and government surveys were identified.

Management implications

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

Future directions

- Identify and formally describe new taxa of conservation significance.

SP 2007-014 Development of interactive identification platforms and content

Team

K Thiele

Context

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

Aims

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

Progress

- Keys to the families Goodeniaceae, Proteaceae, Lamiaceae and Haemodoraceae in Western Australia have been made available through the Herbarium's FloraBase website, and have been updated and errors corrected, often as a result of user feedback.
- A key to all Western Australian species in the family Restionaceae has been completed and made available on Florabase.
- Coding for a key to all Western Australian species of the important family Malvaceae is close to completion.

Management implications

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

Future directions

- Continue to correct and improve all keys as a result of user feedback.
- Complete the key to Malvaceae and publish online in FloraBase.

SP 2003-008 Conservation status and systematics of Western Australian *Acacia*

Team

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.

Progress

- 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.
- Five papers published in *Nuytsia* describing 17 new species of *Acacia* from WA.
- Reviewing a manuscript containing the revision of *A. microbotrya*.

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

- Publish *Acacia microbotrya* revision.
 - Completed an assessment of name changes in *Vachellia* and *Senegalia*
 - On-going description of miscellaneous new Western Australian *Acacia* species.
-

SP 2002-001 Genetic and ecological viability of plant populations in remnant vegetation

Team

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

Context

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

Aims

- Identify and quantify the genetic and demographic factors that affect the viability of plant populations in vegetation remnants. The focus will be on the effects of genetic erosion, inbreeding and pollinator limitation on seed production and seedling fitness.
- Examine and model the relationships between key genetic and demographic factors affecting viability and remnant vegetation characteristics such as size, disturbance and landscape position.
- Develop specific genetic and demographic guidelines for management of remnant populations of the target taxa and general landscape design principles for major plant life-history types that will maximise the probability of population persistence.

- Develop an understanding of the population biology, mating systems and gene flow of flora with distributions centred on the seasonally wet Busselton ironstone communities to inform management for long-term conservation in relation to population viability (population size and degree of connection) and appropriate fire frequency.

Progress

- A paper detailing the genetic structure in the *B. sphaerocarpa* study area has been published in the *Biological Journal of the Linnean Society*.
- Paper on the impacts of fragmentation on pollen dispersal and genetic diversity in *Calothamnus quadrifidus* ssp. *teretifolius* has been published 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.
- Analysis of the genetic diversity, mating system and reproductive biology of *Hakea oldfieldii* has been completed. One paper is in review and another paper is in final preparation. The three population areas in Perth Hills, Busselton and south coast showed significant genetic divergence as expected but there was also significant population divergence within these areas indicating low historical connectivity. Low diversity is associated with historical processes rather than recent fragmentation. Populations were predominantly outcrossed even when severely reduced in size, indicating little effect of inbreeding in small populations, but reproductive parameters were higher in small populations with intact vegetation compared to disturbed sites, highlighting effects of understorey on pollinator abundance and behaviour.

Management implications

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

Future directions

- Prepare papers on mating system variation and reproductive output in *Eremaea pauciflora* and *Eucalyptus wandoo*, and genetic diversity in *E. wandoo* and *C. quadrifidus*.
- Finalise papers on genetic diversity, pollen dispersal and mating systems in *Banksia nivea* ssp. *uliginosa*.
- Finalise papers on reproductive biology and demography in *B. nivea* ssp. *uliginosa*.

SP 2001-004 Translocation of critically endangered plants

Team

L Monks, R Dillon, D Coates, T Llorens

Context

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

Aims

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

Progress

- Infill planting was completed for translocations of seven Critically Endangered plant species at seven sites. Five new translocation sites were set up for three critically endangered plant species.
- Monitoring was undertaken for 40 sites of 27 taxa translocated in previous years.
- Detailed monitoring was undertaken for *Acacia cochlocarpa* subsp. *cochlocarpa* translocation and natural sites and a prescribed burn was undertaken at one translocation site. Post-fire and demographic monitoring will be used to develop PVA models for this species.
- Continued working on publications on flora translocation success criteria.
- Assisted departmental district and regional staff plan and implement a range of flora translocations. Provided advice to departmental staff on translocations proposals submitted for approval.

Management implications

- Translocations lead to the improved conservation status for threatened flora, particularly Critically Endangered plant taxa.
- The improved awareness of best-practice translocation methods for Parks and Wildlife staff and community members undertaking such work, will lead to greater translocation success.
- Further development of success criteria and methods for analysing long-term success, such as the use of population viability analysis (PVA), mating system analysis and genetic variability analysis, will ensure completion criteria are adequately addressed and that resources can be confidently re-allocated to new translocation projects.
- Ongoing monitoring of translocations is providing information on the success of methods used and the probability of long-term success. Close collaboration with district and regional staff on this project then enables this information to be used immediately in other flora translocation projects.

Future directions

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

SP 2001-001 Mating system variation, genetic diversity and viability of small fragmented populations of threatened flora, and other key plants of conservation importance

Team

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 and increase the probability of successful establishment of restored populations.

Aims

- Assess the relationship between effective population size and levels of genetic diversity, and the minimum effective population size for maintaining genetic diversity in natural and restored populations.
- Assess the effects of population size and habitat degradation on mating system parameters that indicate inbreeding or the potential for inbreeding.
- Assess whether reduction in population size, increased inbreeding and reduced genetic variation are associated with any reduction in fitness.
- Assess whether there are differences in the levels of genetic diversity and mating system parameters between rare and common congeners, which will provide a more general understanding of rarity in this flora and how it can be managed.

Progress

- A paper has been submitted on significant genetic structure in *Banksia brownii* associated with three geographically distinct population groups, and the loss of substantial genetic diversity through the extinction of populations across the species distribution covering a range of habitats.
- Data on mating system variation in two sister triggerplant species (*Stylidium affine* and *Stylidium maritimum*) with contrasting breeding systems is currently undergoing re-analysis.
- Seed collections have been completed from a translocated *Banksia brownii* population and 7 natural populations to assess mating system variation and benchmark mating system performance in the translocated population.

Management implications

- Assessment of genetic variation will inform prescriptions for the prevention of inbreeding and maintenance of genetic variation in small fragmented populations of rare and threatened plants, and will facilitate strategies for managing inbreeding and loss of genetic diversity during translocation programs.
- Translocation programs for *Banksia brownii* should continue to mix seed collections from within the three eco-geographic regions, but translocations should not yet be established with seed mixes from different regions. Further translocations using seed collected from the now extinct eastern Stirling Range populations should be considered given the high levels of genetic diversity found in those populations.

Future directions

- Submit paper on the mating system in two *Stylidium* species, *S. affine* and *S. maritimum*.
- Commence mating system study on *Banksia brownii* translocated and natural populations.
- Commence genetic diversity and mating system studies on *Lambertia orbifolia* translocated and natural populations.

SP 2000-015 The population ecology of critically endangered flora

Team

C Yates, D Coates, N Gibson, C Ramalho

Context

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

Aims

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

Progress

- Used the findings of the Montane Heath and Thicket community study to assess the conservation status of the community with the new IUCN Red List for Ecosystems criteria and published the results in a special edition of *Austral Ecology* on Ecosystem Risk Assessment.
- Continued monitoring the demography of the Critically Endangered *Verticordia staminosa* ssp. *staminosa* in relation to a drying climate in south-west Western Australia
- Established micro-climate sensor array in the Ravensthorpe Range to develop climatic layers at appropriate scales for modelling the distribution of short range endemics under the influence of a projected warmer and drier climate.
- Completed an analysis of fire response of threatened flora, prepared fields for the incorporation of fire response information on threatened flora in the Threatened and Priority Flora database and drafted a paper for publication.

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. Using IUCN Ecosystem Risk Assessment criteria the community is ranked as Critically Endangered. 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.

A review and analysis of fire response of threatened flora and the development of fields in the threatened and Priority Flora database will assist in developing improved fire management protocols for threatened flora.

Future directions

- Continue to write up and publish research on the eastern Stirling Range Montane Heath and Thicket Community.
- Continue monitoring *Verticordia staminosa* ssp. *staminosa* and begin analysis of long term monitoring data-set investigating the effects of declining rainfall on the recent dynamics of the population.
- Collect and analyse data from micro-climate sensor array in the Ravensthorpe Range.
- Publish paper on fire response of threatened flora
- Based on Threatened and Priority Flora database records estimate the level of extinction debt for threatened plants in the highly fragmented south west landscape.

SP 1999-010 Seed biology, seedbank dynamics and collection and storage of seed of rare and threatened Western Australian taxa

Team

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

Context

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

Aims

- Provide a cost effective and efficient interim solution to the loss of plant genetic diversity by collecting and storing seed of rare and threatened Western Australian plant species, and thereby provide a focus for flora recovery.
- Increase knowledge of seed biology, ecology and longevity.
- Incorporate all information into a corporate database (WASEED) and provide relevant information on seed availability, seed biology, storage requirements and viability of seed of rare and threatened taxa to assist the development of management prescriptions and preparation of interim recovery plans and translocation plans.

Progress

- 235 seed accessions lodged at the Threatened Flora Seed Centre (164 Declared Rare Flora [DRF], 41 Priority Flora and 30 common).
- 1024 collections of common species accessioned for the Swan Region's *Banksia* Woodland Restoration Project.
- Total number of accessions with seed in the Threatened Flora Seed Centre is now 5130 (2193 DRF, 1091 Priority and 1846 common).
- Seeds of 80% of extant DRF and 23% of Priority taxa in secure storage.
- 4 accessions cleaned and stored (3 DRF, 1 common accession).
- 954 accessions stored for the Swan Region's *Banksia* Woodland Restoration Project.
- 104 germination tests conducted.
- 466 collections quantified and 398 germination tests conducted for the Swan Region's *Banksia* Woodland Restoration Project.
- Provision of seedlings of 18 Critically Endangered and one Endangered species for translocation.

Management implications

- Seed conservation supports the survival of species in the wild by providing the genetic material for reintroduction; seed is provided for translocations of rare species and for restoration of *Banksia* woodland.
- Provision of seed biology and ecology data increases the success of recovery of threatened flora, particularly through knowledge of how pre-treatments may stimulate germination.

Future directions

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

- Continued collaboration with other Australian seed banks through the Australian Seed Bank Partnership and finalise funding from the Australian Seed Bank Partnership.
- Continue collaboration with the Millennium Seed Bank Project, Royal Botanic Gardens, UK.

SP 1998-003 Genetics and biosystematics for the conservation, circumscription and management of the Western Australian flora

Team

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

Context

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

Aims

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

Progress

- A paper has been published in the *Botanical Journal of the Linnean Society* showing that there is significant population genetic structure in *Eremophila microtheca* and *E. rostrata* that supports subspecies entities in *E. rostrata* and indicates a taxonomic assessment is required for *E. microtheca*.
- Subsequent to the genetic study, a morphological assessment of *E. microtheca* has led to a new subspecies *E. microtheca* subsp. narrow leaves being nominated and listed as threatened.
- Analysis of AFLP markers for putative taxa of *Synaphea* from the Pinjarra Plain has identified genetic discontinuities between populations to inform taxonomic revision.
- Additional samples were analysed in a phylogeographic study of *Calothamnus quadrifidus* that confirmed the phylogeographic patterns indicating the presence of historical refugia in the Kalbarri/Shark Bay region, along the south coast and on the inland granite outcrops and greenstone ranges. Haplotype distribution reflecting evolutionary patterns supports the recent taxonomic revision of the species. A paper has been published in *Heredity*.
- Analysis of genomic data in *Calothamnus quadrifidus* is being undertaken to determine patterns of diversity in the nuclear genome in relation to the 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. A paper on genetic diversity has been published in the *Biological Journal of the Linnean Society*. A paper on clonality is in press in *Heredity*.
- A paper has been published in *Tree Genetics and Genomes* detailing the four genetic entities found within the *Acacia microbotrya* species complex that are consistent with four of the five morphological taxa in the complex, *A. microbotrya*, *A. daphnifolia*, *A. amblyophylla* and *A. microbotrya* Dandaragan variant. The fifth morphological taxon, *A. splendens* could not be resolved as a distinct genetic entity and was closely associated with *A. microbotrya* Dandaragan variant. Genetic evidence also supported morphological indications of a hybrid zone in the geographic area of overlap in the distributions of *A. microbotrya* and *A. daphnifolia*.

Management implications

- Assessment of the genetic structure within collections of *Synaphea* from the Pinjarra Plain will inform taxonomic revision and determine the identity of questionable populations of rare taxa.
- Assessment of genetic differentiation in *Eremophila microtheca* and *E. rostrata* confirmed sub-specific taxa enabling assessment of conservation status.
- Assessment of genetic differentiation in *Calothamnus quadrifidus* has supported taxonomic revision of the group.
- Resolution of the taxonomic status of *Pityrodia scabra* subsp. *dendrotricha* (previously *Pityrodia* sp. Yilgarn) has enabled conservation assessment as Priority Three, as it is known from several populations that are not under immediate threat.
- Clarification of taxonomic status of *Platytheca* sp. Sabina, *Hakea* aff. *prostrata*, and *Hydrocotyle scutellifera* and associated taxa will enable evaluation of conservation status and implementation of conservation actions if required.
- High genetic diversity, low levels of clonality and small clone size in *Lepidosperma* sp. Mt Caudan indicate germplasm collections for conservation purposes should be taken at least one meter apart. Lower diversity, moderate levels of clonal reproduction and greater clone size in *L. sp.* Parker Range suggest germplasm collections should be at least four meters apart and comprise all populations.
- Assessment of genetic variation and hybridisation in the *Acacia microbotrya* species complex has largely supported taxonomic revisions while also presenting strong evidence for *A. microbotrya* Dandaragan variant to be elevated to species level. This taxonomic resolution will guide management of the geographically restricted taxa in the complex as well as the management of the more widespread taxa of commercial interest.

Future directions

- Taxonomic revisions of *Platytheca* sp. Sabina, *Hakea* aff. *prostrata*, and *Hydrocotyle scutellifera* and associated taxa will be completed.
- Identification of taxonomic entities in the *Synaphea* complex of the Pinjarra Plain will be completed.
- Analysis of genomic data of *C. quadrifidus* will be completed.

Ecosystem Science

Program Leader: Lachie McCaw

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

SP 2014-001 Understanding the changing fire environment of south-west Western Australia

Team

L McCaw, B Ward

Context

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

Aims

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

Progress

- Trends in lightning fire activity for the Warren Region over the period 1977-2014 were analysed, and a statistically significant trend of increasing lightning ignition was identified. No strong association between lightning ignition and vegetation type was identified, other than that ignitions were relatively less frequent in coastal shrublands and Agonis woodlands, which may be explained by the lower abundance of large trees.
- Datasets of Soil Dryness Index from 1980 to 2014 and forest fuel moisture indices from 1990 to 2014 were compiled in readiness for analysis of trends.
- The O'Sullivan (Northcliffe) bushfire was reconstructed in order to identify significant fuel and weather factors that influenced the behaviour of the fire during different phases of its spread.

Management implications

Understanding the factors that influence the location and timing of bushfire ignitions is important for developing effective management strategies to minimise the risks posed by unplanned fires, and to guide the level of resourcing required for bushfire suppression in different management areas. Lightning is an important cause of bushfire ignition in south-west Western Australia and the area burnt by lightning-caused fires has been disproportionately large relative to the number of ignitions during the past decade. Better understanding of the links between climatic patterns and lightning ignition could provide advance warning of above-normal activity and the opportunity for improved preparation and resource deployment.

The increased occurrence of large and damaging bushfires in the past five years has led to a re-focus on the importance of managing fuels with prescribed fire. In order to achieve a safe and effective prescribed burning program there is a need to understand how weather and climate influence opportunities for burning, and how these opportunities may be changing over time.

Future directions

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

SP 2013-004 Restoring natural riparian vegetation systems along the Warren and Donnelly Rivers

Team

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

Context

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

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

Aims

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

Progress

- DNA optimisation for genotyping by sequencing of 288 samples representing 12 populations across a climate gradient for each of *Astartea leptophylla*, *Callistachys lanceolata* and *Taxandria linearifolia* along the Warren River has been completed and samples sent to Genomic Diversity Facility at Cornell University for sequencing.
- Seed collections from 12 populations for each of the three species have been prepared for planting and two experimental plots (3m x 3m) have been set up at each of two sites in the revegetation area with seed of *Astartea leptophylla* and *Callistachys lanceolata* sown.
- Preliminary analysis of sequencing results has been completed to identify genetic structure present across the catchment for each of the three species.
- A manuscript from the climate modelling under current and future climate change scenarios has been prepared 'A spatially explicit framework to guide seed provenance for riparian ecological restoration in a climate change context'.

Management implications

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

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

Future directions

- Finalise analysis of genomic data from genotyping-by-sequencing results to determine genetic adaptation between populations and climate zones for three species.
- Sample from experimental plantings to send for genomic analysis to assess establishment and performance to determine any effects of adaptation to drier environments on current performance of germplasm in revegetation projects.
- Complete outlier analysis and analysis of association between allele frequencies and important ecological variables to identify potential adaptive loci.

SP 2012-038 Responses of terrestrial vertebrates to timber harvesting in the jarrah forest

Team

A Wayne, C Ward, C Vellios, M Maxwell

Context

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

Aims

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

Progress

- 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 2001 and 2013. Previously an average of 10-12 individuals (up to 33) were detected per transect per night. In the last 12 months, up to four individuals have been detected per transect per night, providing early encouraging signs that some recovery may be underway.
- The ngwayir has declined and remains at almost undetectable levels across the remainder of upper Warren area. The ngwayir population in the upper Warren was the largest known population, is genetically distinct, and had higher genetic diversity than Bunbury and Busselton populations.
- Data from previous trapping and spotlighting have been collated and validated. Analyses and preparation for publication are underway.
- Data from this study provide important evidence indicating that seven species have declined in succession since 1994 in the upper Warren area (dunnart, native bush rat, wambenger, quenda, ngwayir, woylie and western brush wallaby), to similar extents (>80%), at similar rates and with no sign of significant or sustained recovery. Three species have recently increased significantly (common brushtail possum, chuditch and tammar wallaby).

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.
- Decline of multiple species of marsupial in the upper Warren area, of which the ngwayir is one (the others being dunnart, native bush rat, wambenger, quenda, woylie and western brush wallaby) is of serious concern requiring action, especially given the high conservation value of the area and the importance of the populations it supports including the species already mentioned and others such as the numbat, tamar wallaby and chuditch. Understanding the factors responsible for these population changes provides critical context for informing management of fauna in areas subject to timber harvesting and other management activities.

Future directions

- A paper on woylie responses to timber harvesting will be submitted for publication shortly.
- A paper on the multiple species declines in the Upper Warren region will be submitted for publication by the end of 2015.
- The responses to timber harvesting by other medium-sized mammals will be analysed and prepared for publication over the next 12 months.
- The spotlight data on possums is being analysed as part of an Honours project by Adrian Barrett, Murdoch University for completion in 2016.

SP 2012-036 Fire behavior and fuel dynamics in coastal shrublands

Team

K Knox, L McCaw

Context

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

Aims

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

Progress

- Fire behaviour data have been collected from three sites (Albany, Frankland and Moora districts). Further sites have also been established in these districts and data will be collected once conditions are suitable for burning.
- Data from fires in Western Australian shrublands have been included in a fire spread model developed collaboratively by researchers from Australia, New Zealand and Mediterranean Europe. A paper describing the data sources and development of the model was published in the *International Journal of Wildland Fire*. The model will also be presented in the format of a field guide for convenient use by fire practitioners.

Management implications

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

Future directions

- Collect fire behaviour from planned burns as these are implemented.
- Plan and conduct further experimental burning to quantify threshold conditions for sustained fire spread in shrublands of different structure and time since fire.
- Further evaluate and verify the performance of the collaboratively-developed fire spread model for Western Australian shrublands.
- Expand the scope of the project to include quantification of fire severity and patchiness at the operational burning scale.

SP 2012-029 Long term response of jarrah forest understorey and tree health to fire regimes

Team

N Burrows, B Ward

Context

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

Aims

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

Progress

- A final assessment of all plots was carried out in March 2015.
- The data base has been checked and analysis has commenced.

Management implications

Further data analysis is required to assess the long term effects of fire on floristic composition and richness, and implications for management. Being one of a few long term studies of its kind around the world, the findings of this research will be important for guiding fire management policy and planning for community protection and biodiversity conservation.

Future directions

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

SP 2012-027 North Kimberley Landscape Conservation Initiative: monitoring and evaluation

Team

I Radford, R Fairman

Context

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

Aims

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

Progress

- This project is now into its fifth year of monitoring in the North Kimberley and a total of 86 sites have been surveyed for mammals and vegetation structure, and 101 sites for vegetation alone. Ten rainforest sites have been surveyed at least once. Twenty five sites at the Mitchell Plateau have been surveyed over four consecutive years. Sites at King Leopold Range National Park have been surveyed four times, Prince Regent twice and Bachsten Creek, Drysdale River and Mt Elizabeth once.
- Data from monitoring sites, combined with GIS data layers, confirm that mammal distribution patterns are strongly influenced by vegetation cover, cattle impacts and fire regime particularly the frequency of late dry season fires.
- An inverse relationship between the amount of surrounding country burnt, ground layer vegetation cover and mammal abundance confirms the importance of prescribed burning to conserve vegetation cover needed by mammals. These findings are presented in a scientific paper published in *PLOSone*.

- At the regional scale, monitoring shows that most Kimberley mammal species recorded historically are still present and that abundance and richness values are well above threshold values seen in the Northern Territory where mammal populations have collapsed. Mitchell Plateau, Prince Regent and Bachsten Creek have the highest mammal abundance and richness, King Leopold Range intermediate, and King Edward River, Drysdale River and Mount Elizabeth had the lowest mammal abundance/richness and are of greatest conservation concern.
- Mammal abundance and richness has increased at the Mitchell Plateau compared with earlier surveys by the Department from 1994 to 2010. Mammal species have recolonised habitats and become more abundant with implementation of LCI initiatives since 2008, including greater use of planned burning early in the dry season and introduction of a cattle culling program.
- The monitoring program has recorded most of the mammal species that would be expected at the regional scale. Exceptions are the black-footed tree rat (presumed extinct), the brush tailed phascogale (recently sighted at Mitchell Plateau but not recorded in surveys), the nabalek rock wallaby (only confirmed on off-shore Kimberley Islands) and the rock ringtail possum (not recorded in monitoring but reported elsewhere in the region).
- The status of species unaccounted for during the monitoring program is being investigated further using nest boxes to monitor specialist arboreal species and through a collaborative PhD project with the University of Melbourne on tree hollow distribution and limitation of arboreal mammals.

Management implications

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

Future directions

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

SP 2012-002 Climate-resilient vegetation of multi-use landscapes: exploiting genetic variability in widespread species

Team

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

Context

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

Aims

The project will test the following alternative hypotheses:

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

Progress

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

Management implications

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

Future directions

Complete final scientific paper on genomic architecture of adaptation.

SP 2011-020 Long-term stand dynamics of regrowth karri forest in relation to site productivity and climate

Team

L McCaw, B Ward

Context

This project provides information to underpin the management of karri in the immature stage of stand development (25-120 years old). Regenerated karri stands have important values for future timber production, biodiversity conservation and as a store of terrestrial carbon. Immature stands regenerated following timber harvesting and bushfire comprise more than 50,000 hectares and represent around one third of the area of karri forest managed by the department. There are a number of well-designed experiments that investigate the dynamics of naturally regenerated and planted stands managed at a range of stand densities. These experiments span a range of site productivity and climatic gradients in the karri forest, and have been measured repeatedly over a period of several decades, providing important information to support and improve management practices. This project addresses emerging issues likely to be of growing importance in the next decade, including climate change and declining groundwater levels, interactions with pests and pathogens, and increased recognition of the role of forests in maintaining global carbon cycles.

Aims

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

Progress

- Tree growth and form data collected at a spacing experiment in Wheatley forest block between 1992 and 2012 were compiled and analysed to test the influences of initial planting density and survival. A draft manuscript was commenced.
- Information about growth rate and fuel accumulation in karri regrowth stands was included in a draft silvicultural burning manual.

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

- 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.

SP 2011-019 Management of invertebrate pests in forests of south-west Western Australia

Team

J Farr, A Wills

Context

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

Aims

- Investigate aspects of pest organism biology, host requirements, pathology and environmental conditions (including climatic conditions) that influence populations.
- Determine distribution of the invertebrate pests, including outbreak boundaries and advancing outbreak fronts, using aerial mapping, remote sensing and road surveys.
- Measure relative abundance of invertebrate pests, including quantitative population surveys and host/environmental impact studies where appropriate and/or possible.
- Utilise appropriate monitoring technologies including GIS and remote sensing.
- Liaise with land managers and the community regarding responses to pest insect outbreaks.

Progress

- Pheromone trapping of GLS was used to quantify the 2014/15 GLS population level.
- More than 250,000 ha of forest was defoliated by GLS in 2010/2011. GLS populations have since decreased from this peak. GLS population changes indicate density dependent mortality is operating in this population decline. The mechanism of density dependent mortality is not yet understood.
- The relationship between November and January populations of GLS larvae was investigated to allow integration of historical and current monitoring data.
- A report summarising results of GLS monitoring 2010-2014 has been prepared and circulated to managers.
- A science information sheet describing the link between GLS outbreak and anomalously low rainfall has been prepared.
- *Cardiaspina fiscella* incidences are increasing in south-west WA and a science information sheet describing the behaviour of this pest insect is being prepared.

Management implications

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

- Integration of GLS population and impact data from two major outbreak events will facilitate analysis of links between climatic factors and outbreak development. Preliminary analysis indicates a strong coupling between GLS outbreak and periods of below-normal rainfall at annual or longer timescales.

Future directions

- Refine relationship between moths captures and Normalized Difference Vegetation Index to investigate the spatial structure of the onset and development of GLS outbreaks and the relationship between defoliation rates and leaf area index.
- Finalise and publish findings from investigations of long term population cycles of GLS.

SP 2011-011 Protecting the safe havens: will granite outcrop environments serve as refuges for flora threatened by climate change?

Team

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

Context

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

Aims

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

Progress

- Completed integration of plant species records from the floristic survey of 450 plots with environmental measurements of 17 GOs in a database.
- Phylogeographic analysis of *Kunzea pulchella* and *Stypanandra glauca* confirmed that GOs have provided refugial opportunities for species during previous cycles of climate change. Use of LiDAR and other multispectral remotely sensed data have confirmed that GOs will provide refugial opportunities for species under the influence of a drying climate.

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

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

SP 2010-011 Fire regimes and impacts in transitional woodlands and shrublands

Team

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

Context

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

Aims

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

Progress

- A multi-century time since fire chronosequence of 76 plots has been established in gimlet woodlands. A summary of previous research on estimating the time since fire of long-unburnt woodlands and documenting changes in plant communities with time since fire was published in *Landscopemagazine*.
- In collaboration with CSIRO Land and Water Flagship, ant communities were sampled across the gimlet chronosequence. Ant functional groups changed in richness and abundance with time since fire in a manner consistent with predictions based on how previously-documented changes in vegetation structure, such as in insolation and litter cover, would affect habitat suitability for ants. Dominant Dolichoderinae and Hot-Climate Specialists were prominent in more-open recently-burnt and long-unburnt habitat, and

Cold-Climate Specialists more prominent in less-open habitat at an intermediate time since fire. This work has been published in *Forest Ecology and Management*.

- In collaboration with BirdLife Australia, bird surveys were conducted across the gimlet chronosequence. Bird species showed a variety of responses to increasing time since fire, including decrease, increase, bell-shaped and delayed (mature woodland-dependent).
- Gimlet growth ring increments have been sampled and measured on 78 individuals at 26 sites to resolve uncertainty in the ageing of long-unburnt stands.
- Data from plots in gimlet woodland, mallee and mallee-heath were contributed to a national-scale synthesis of post-fire response traits of plants, leading to a paper to be published in *Science of the Total Environment*. The woody flora of all three habitats was numerically dominated by obligate seeding species.

Management implications

- Changes in vegetation structure, cover and hazard across the gimlet chronosequence indicate maximum community flammability at intermediate times since fire, supporting the revision of fire behaviour ratings for eucalypt woodlands in the GWW.
- The dominance of obligate seeding species in gimlet woodlands, mallee and mallee-heath suggests any decrease in intervals between fires, such as plausibly may occur under future shifts in climate, would have adverse biodiversity conservation consequences.
- Current fire management in gimlet woodlands aims to minimise wildfire occurrence, which is consistent with the maintenance of functional diversity at a regional scale given the long time periods over which post-fire changes take place in vegetation structure and other elements of the biota.
- The combination of recent large wildfires and predicted fire-facilitating climate changes suggest that future shifts in the relative dominance of some elements of the biota are likely if extensive wildfires further reduce the occurrence of mature woodlands.
- Records of *Camponotus* sp. (terebrens gp.), the sole host of the larvae of a critically endangered butterfly (Arid Bronze Azure, *Ogyris subterrestris petrina*), are being used to direct searches for new butterfly populations.

Future directions

- Complete manuscript preparation on alien plant threats and invasion pathways in the GWW.
- Refine models estimating the time since fire of long-unburnt gimlet woodlands through the use of the growth ring increment data.
- Sample tree size and dominance widely across the GWW to generate a robust age-class distribution of gimlet woodland and hence assess whether recent extensive wildfires are unprecedented over the period in which existing gimlet stands developed.
- Compare fire regime parameters and post-fire response traits of plants in woodlands of the GWW with woodlands elsewhere in Australia, to investigate if the grouping of these communities as functionally analogous is justified.
- Commence measurement of carbon pools across the gimlet chronosequence to determine the role of fire management in carbon sequestration.

SP 2007-008 Fire regimes and biodiversity decline in the Kimberley test

Team

I Radford, R Fairman

Context

Recent studies have shown declines in some elements of biodiversity across northern Australian savannas. Biodiversity declines in otherwise intact landscapes have been attributed to increased intensity and frequency

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

Aims

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

Progress

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

Management implications

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

Future directions

This project is now complete.

SP 2006-008 Identification of seed collection zones for rehabilitation

Team

M Byrne, D Coates, S McArthur

Context

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

Aims

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

Progress

- A paper on population genetic structure and phylogeographic patterns in *Kennedia coccinea* is in review and seed sourcing strategies for this species are being developed.
- A paper on population genetic structure and phylogeographic patterns in *Bossiaea ornata* is in review and seed sourcing strategies for this species are being developed.
- Analysis of microsatellite variation and cpDNA variation in *Allocasuarina humilis* has been completed and drafting of a paper is well underway.
- Analysis of microsatellite variation and cpDNA variation in 28 eight populations of *Banksia sessilis* is near completion and drafting of a paper has commenced.
- Analysis of cpDNA variation in marri (*Corymbia calophylla*) has been completed and genotyping using microsatellites has been completed ready for analysis.

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*, *Bossiaea ornata* and *Allocasuarina humilis* indicate that seed collected from the same landscape management unit as the area to be rehabilitated would be an acceptable seed-sourcing strategy. Alternatively, where seed is not readily available from the relevant landscape management unit then use of seed from nearby areas in adjacent landscape management units would also suffice. This information has been used to update seed collection zones for forest rehabilitation in the *Forest Management Plan 2014-2023*.

Future directions

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

SP 2006-003 FORESTCHECK: Integrated site-based monitoring of the effects of timber harvesting and silviculture in the jarrah forest

Team

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

Context

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

Aims

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

Progress

- Monitoring was undertaken at seven grids in the eastern part of Blackwood District, and at one existing and two new sites in Perth Hills to complete the annual monitoring cycle. A total of 65 monitoring grids have now been established in jarrah forest.
- Trials were conducted in Donnelly District to evaluate the use of remote cameras for detecting terrestrial vertebrates in karri forest. This technique shows promise for surveying presence and level of activity of a range of species, including feral predators.
- An overall analysis of the Forestcheck data from the 10-year monitoring period 2002–12 was completed and associated scientific papers are being prepared. A review process has been initiated to assess the capacity and process of delivery for monitoring into the future.
- Seven monitoring grids in Wellington District in the Jarrah North West and Jarrah North East forest ecosystems were burnt by the large Lower Hotham bushfire in February 2015, and a further two grids were disturbed during fire suppression operations. Post-fire assessment of coarse woody debris consumption was completed, and plot infrastructure damaged by fire was replaced.

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.

Findings from the project continue to inform a variety of forest management policies and practices and have been incorporated in periodic revision of silvicultural guidance documents. Monitoring data have been used to verify predictive models for forest growth and species occurrence.

The network of Forestcheck grids also provides a framework for monitoring responses to random disturbance events such as bushfires and extreme droughts, and for examining the impacts of a changing climate over the longer term.

Future directions

- Finalise analysis of data from the 10-year monitoring period (2002-2012) and publication of 10-year results.
- Review monitoring protocols and incorporate new techniques where these will improve efficiency and quality of data collected.
- In consultation with Forest and Ecosystem Management Division and the Forest Products Commission determine a future program of monitoring for 2015 to 2018.

SP 2006-001 Monitoring post-fire effects from the 2001 Nuyts wildfire

Team

G Liddelow, B Ward, L McCaw

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.

Progress

A manuscript reporting on recovery of overstorey and mid-storey trees and eucalypt regeneration has been accepted for publication in the on-line journal *Fire Ecology*.

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 inform planning for recovery actions for tall open forests following the large O'Sullivan (Northcliffe) bushfire that burnt almost 100 000 ha of the Warren Region during February 2015.

Future directions

- This project is completed and will be closed.

SP 2004-004 Burning for biodiversity: Walpole fine-grain mosaic burning trial

Team

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

Context

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

Aims

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

Progress

- Field work is complete. Data are being compiled, fungi and invertebrate collections are being sorted and documented, and data analysis has commenced.
- A paper describing the theory of fire-induced mosaics, how to describe and characterise mosaics and operational challenges in creating fire mosaics is being prepared for publication.
- A paper on the response of *Banksia quercifolia* has been submitted for publication.

Management implications

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

Future directions

- Complete data analysis and publish papers.
- Commence technology transfer through formal and informal presentations and publications.

SP 2004-003 Management of environmental risk in perennial land use systems

Team

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

Context

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

Aims

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

Progress

- An information sheet on weed risk and the FFI CRC assessment protocol has been completed and published on the FFI CRC website.
- New weed risk assessments have been completed for native forage species that may be used outside their natural range and these have been published online on the FFI CRC website.
- A paper describing the FFI CRC environmental risk strategy for minimising the risk to the environment from agriculturally useful species was presented at the 5th Victorian Weeds Conference in Geelong, Victoria. The audience represented a wide range of organisations engaged in the control of environmental weeds from policy development to identification, monitoring and on-ground control.
- The concepts of weed and genetic risk have continued to be promoted in FFI CRC publications and raised in forums with stakeholders in Western Australia and nationally.

- An environmental risk strategy and framework was developed for the FFI CRC. All the components have been published, promoted and implemented. Assessments and other material prepared within this project are published on the Department of Parks and Wildlife website.
- The weed risk assessment protocol, genetic risk assessment protocols, species management guides and field trial guideline have been prepared and published for some species promoted by the FFI CRC to inform management to minimise the risk to natural environments.
- The environmental risk strategy, framework and its components have been promoted widely and a weed risk note provided for a publication on tropical grasses published by the FFI CRC.

Management implications

- Promotion of the concepts of weed and genetic risk management both within and outside the FFI CRC and the development and use of appropriate assessment techniques will reduce the risk of large-scale plantings of new perennial species introduced from outside Australia, native species used outside their natural range or newly developed cultivars becoming environmental weeds.
- Adoption of the genetic risk assessment process will enable the risk of genetic contamination and hybridisation to be assessed on a site-specific basis. This will help in the development and implementation of processes to manage these risks. The information may also indicate where further research is needed to understand gene flow in the environment. Guidelines and risk assessment will inform species selection and trial and planting plans to minimise the risk of agriculturally useful species to native environments during research, breeding and production system development.

Future directions

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

SP 2003-004 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

Team

N Burrows, G Liddelow, B Ward, Goldfields Regional Staff, Prof T Bragg (University of Nebraska, Omaha)

Context

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

Aims

- Develop efficient, effective and safe introduced predator (fox and feral cat) control technologies for the interior rangelands and the arid region.

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

Progress

- Cat, fox and wild dog aerial baiting carried out on Lorna Glen in July 2014 as part of the Western Shield program was partially effective with the feral cat population reduced by ~30% from an activity index high of 22.4. Radio tracking however, suggested a cat reduction of 60%. Deterioration of track count survey lines due to heavy rain prior to the survey may have contributed to this discrepancy.
- This year for the first time, a survey was also carried out on Earraheedy, which has never been baited. The cat density was about 50% higher than on Lorna Glen.
- The field work component of a PhD project to investigate interactions between wild dogs/dingoes and wild cats is complete and data analysis and write-up are underway. The study is testing the hypothesis that there is an inverse relationship between dog and cat density. The management implication is that retaining dingoes could result in a reduction in cats.
- A report on 10 years of monitoring vertebrate fauna has been completed and shows that some taxa have increased in abundance, possibly in response to management actions. This work is being prepared for publication.
- Mulgara (*Dasycercus cristicauda*) population has declined on Lorna Glen, but is still significantly higher than before baiting commenced in 2003 and is about double the population on Earraheedy.
- The fire management plan continued to be implemented, including further installation of fuel-reduced buffers around some fire management cells and some core ignition using aircraft. A wildfire started by lightning in late September 2014, and which had the potential to threaten the predator exclusion compound containing threatened fauna, was stopped by the buffer burning.

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

- Assess and report on the effectiveness of wild cat and dog baiting to be undertaken in July 2015. Trail cameras will be evaluated for their utility for assessing predator density before and after baiting.
- Prepare a paper for publication reporting on 10 years of biodiversity monitoring on Lorna Glen.
- Carry out a biological survey of Earraheedy.
- Survey wild dogs, cats and mulgara on Earraheedy where there has been no introduced predator control, and compare results with Lorna Glen.
- Continue to implement the fire management plan including buffer burning and aerial patch burning. Carry out patch-burning in the predator-proof compound.

SP 2001-005 Landscape and fire management interactions and their effects on distribution of invertebrate biodiversity

Team

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.

Progress

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

Management implications

The finding of high beta-diversity at small geographical scale (tens to a few hundred metres) within valley geomorphic units expands on the findings of other studies in the jarrah forest that show broad similarity of assemblages (low to medium beta-diversity) at medium geographical scales (up to a few tens of kilometres), and higher beta-diversity at large geographical scales. Low frequency of occurrence of most species makes it difficult to draw conclusions about the refugial nature of southern aspects, though for some species aspect is an apparently important determinant of local distribution. Greater trapping effort over a longer duration would be required to confirm this hypothesis. Disturbance at any geographical scale within the valleys is likely to have a greater effect on invertebrate species composition than disturbance at such a scale in upland jarrah forest.

Future directions

- Further analysis and writing is dependent on opportunity within the context of higher priority work
- Analyse the dataset using non-metric multidimensional scaling ordination.
- Write up and publish results in a refereed journal.

SP 2000-003 Hydrological response to timber harvesting and associated silviculture in the intermediate rainfall zone of the northern jarrah forest

Team

J Kinal

Context

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

Aims

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

Progress

- Monitoring of groundwater levels, streamflow, stream salinity and stream turbidity continued in Yarragil 6C (treated catchment) and Wuraming (control catchment).
- Yarragil 4X (treated catchment) was not monitored during winter 2014 because the corroded mild-steel V-notch weir plate was being replaced by a stainless steel weir plate.
- Monitoring of groundwater levels, streamflow, and stream salinity continued in Yarragil 4L, which was thinned in the mid 1980s, to examine the effect of thinning on stream water quality and quantity.
- A paper reviewing the long-term hydrological response to thinning in Yarragil 4L is in preparation.

Management implications

- These catchments provide a unique long-term record of the hydrological response of the jarrah forest to climate change and forest management practices.
- Monitoring in these catchments contributes to reporting to KPI 10 for the *Forest Management Plan 2014-23* which relates to stream condition and groundwater level within fully forested catchments.
- Monitoring in these catchments helps inform understanding of silviculture for water production.

Future directions

- Continue monitoring of groundwater levels, streamflow, stream salinity and turbidity and rainfall.
- Re-measure forest density along fixed transects in Yarragil 4X and 6C to determine the forest regeneration response to the timber harvest and silvicultural treatments.
- The mild-steel V-notch weir plate in Yarragil 4L is corroded and should be replaced by a stainless steel plate to extend the operational life of the weir for ongoing stream monitoring.
- Re-measure tree growth in Yarragil 4L to determine the long-term hydrological response to thinning, and write a paper.
- Examine the feasibility of a second thinning in Yarragil 4L, 35 years after the previous thinning, with a view to informing silviculture for water production.

SP 1999-021 Evaluation of key soil indicators of sustainability in Australian mediterranean forests (Indicators 4.1d, 4.1e)**Team**

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.

Progress

- No further work was undertaken on this project during 2014-15.

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

This project will be terminated.

SP 1998-015 The effect of wildfire on forest fungi

Team

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.

Progress

- Analysis has been completed and a manuscript is being prepared.
- 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

- Prepare and submit a manuscript for publication during 2015-16.
- Once publication is completed the project will be closed.

SP 1998-007 Genetic analysis for the development of vegetation services and sustainable environmental management

Team

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

Context

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

Aims

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

Progress

- A paper on phylogeographic patterns and genetic diversity in *Grevillea paradoxa* and *Melaleuca nematophylla* is under review with the *Journal of Biogeography*. In *G. paradoxa* haplotype diversity within populations was low, diversity was moderate overall and there was a phylogeographic signal in chloroplast DNA. Nuclear diversity was low and genetic differentiation among populations was moderate to high with no signal of isolation by distance. In *M. nematophylla* haplotype diversity within populations was low, diversity was moderate overall and there was a phylogeographic signal in chloroplast DNA. Nuclear diversity was low and genetic differentiation among populations was moderate with a signal of isolation by distance.
- A paper on phylogeographic pattern and genetic diversity in *Mirbelia* sp. *bursarioides* and *Grevillea globosa* has been drafted for *The Botanical Journal of the Linnean Society*. In *M.sp. bursarioides* haplotype diversity within populations was low, diversity was moderate overall and there was no phylogeographic signal in chloroplast DNA. Nuclear diversity was moderate and genetic differentiation among populations low to moderate with a signal of isolation by distance. In *G. globosa* haplotype diversity within populations was low and diversity was low overall. There was no phylogeographic signal in chloroplast DNA. Nuclear diversity was moderate and genetic differentiation among populations was low with a signal of isolation by distance.

- A paper on genetic patterns in *Acacia ancistrocarpa* and *A. atkinsiana* has been drafted. *Acacia ancistrocarpa* has moderate haplotype diversity with most populations showing specific haplotypes. Nuclear diversity was moderate with little genetic structure across the Pilbara populations of this widespread species. In contrast, the Pilbara endemic, *A. atkinsiana* had low haplotype diversity with little geographic structure. Nuclear diversity was low and genetic differentiation among populations was moderate.
- Studies have commenced on another eight species in the Pilbara for the identification of seed collection zones. Collections for DNA extraction have been completed for four species, *Petalostylis labicheoides*, *Indigofera monophylla*, *Senna glutinosa* and *Corymbia hamerslyana*, and are underway for four other species, *Acacia pruinocarpa*, *Acacia hilliana*, *Acacia spondophylla* and *Mirbelia viminalis*. Microsatellite genotyping and analysis has been completed for *Petalostylis labicheoides*, *Indigofera monophylla* and *Senna glutinosa*.

Management implications

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

Future directions

- Genetic diversity and phylogeographic patterns will be investigated in four more species in the Pilbara.
- Seed collection and restoration population establishment guidelines are being determined for the four species from the Midwest region.

Wetlands Conservation

Program Leader: Adrian Pinder

The Wetlands Conservation Program undertakes research in a range of disciplines to support the management of wetlands in the State's conservation estate. Surveys of aquatic flora and fauna, at scales ranging from individual wetlands to regions, provide knowledge of patterns in the distribution of aquatic biodiversity required for conservation reserve design, assessment of threatened species and communities, prioritisation of on-ground management and assessment of environmental impacts. Such surveys, along with targeted physical and biological monitoring programs, provide managers with information on effectiveness of management in protecting wetlands and rivers (e.g. management of the south-west forests) and effects of threatening processes such as altered hydrology and feral animals. Altered hydrology, such as that resulting from drainage, land-use changes and water resource development, is one of the major threats to the State's wetlands. The program undertakes research to understand hydrological processes and how to minimise or mitigate changes to protect aquatic biodiversity.

SP 2015-017 Responses of aquatic invertebrate communities to changing hydrology and water quality in streams and significant wetlands of the south-west forests of Western Australia.

Team

M Pennifold, A Pinder, L Lewis

Context

Aquatic habitats in the south-west of WA are under increasing threat from changes in hydrology, water quality and fire as a result of the drying climate and historical and current land use. The south west of Western Australia has had a significant reduction in rainfall since the 1970s and it is predicted that by 2050 there will be little stream inflow into water supply dams. At present, there is an inadequate understanding of the responses of aquatic communities to these threats to inform the management of many aquatic systems in the Forest Management Plan (FMP) area, including the Muir-Byenup Ramsar wetlands.

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

Aims

- To address KPI1 of the 2014-2023 FMP by monitoring the condition of currently healthy streams in relation to reduced rainfall and forest management practices.
- To address KPI3 of the 2014-2023 FMP by determining responses of faunas of high value Warren region wetlands to changes in hydrology, water chemistry and fire over the last 10 to 20 years.
- Provide baseline data for some internationally significant wetlands, e.g. Lake Muir.
- Use the above information to report on the current conservation significance of key DPaW managed wetlands and their response and vulnerability to threats.

Progress

- A journal article is being prepared in collaboration with scientists from CSIRO in Canberra: "Whole of landscape modelling of compositional turnover in aquatic macro-invertebrates informs conservation gap analysis: an example from south-west Western Australia."

- Conducted spring 2014 and summer 2015 sampling of aquatic invertebrates in Muir-Byenup Ramsar wetlands.
- Commenced processing Muir-Byenup invertebrate samples.

Management implications

- Re-surveying the Muir-Byenup Ramsar and other high value wetlands will provide the region with knowledge of how these wetlands have responded to threats over the last 20 years. This, in conjunction with results from the peat wetlands project (SPP2014-24), will help the Warren Region to make decisions about protecting remaining high conservation value wetlands versus taking remedial action at those where condition is declining.
- Forest Management Plan commitments will be met with regard to measuring and assessing change in condition of 1) currently healthy (reference condition) stream ecosystems (KPI1) and 2) Ramsar and nationally listed wetlands (KPI3). Results of these will inform future forest management practices.

Future directions

- Identify Muir-Byenup invertebrates collected in 2014/2015.
- Publish report with summaries of 10 year trends (2005 to 2015) for all stream monitoring sites.
- Re-sample streams in 2016, with a focus on those considered to be in reference condition or in minimally disturbed catchments, to provide long-term data on the response of aquatic invertebrate communities to declining rainfall and forest management.
- Continue to up date fire and logging history for catchment areas.
- Publish further papers examining impacts of declining rainfall and forest management practices on macroinvertebrate diversity in forest streams.
- Re-survey nationally important Warren Region wetlands previously sampled by Horwitz in 1997 (e.g. Owingup, Lake Jasper, Doggerup, Marringup, Mt.Soho Swamp) and identified as priorities in the Warren Region Nature Conservation Plan.

SP 2015-002 South West Wetlands Monitoring Program (SWWMP)

Team

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

Context

Substantial decline in wetland condition has been observed across the south-west of Western Australia over the past 100 years, particularly in the Wheatbelt, almost certainly with ongoing loss of biodiversity. The most pronounced changes to wetlands have been associated with salinisation and altered hydrology following clearing of native vegetation in catchments. Broad-scale clearing has largely ceased but hydrological and fragmentation processes will continue to be expressed for many decades. Changes in rainfall patterns are also resulting in significant changes to wetland hydrology, water chemistry and habitats.

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

Aims

- To contribute to improved decision making in wetland biodiversity conservation by 1) providing analyses of long and short-term changes in surface water quantity and quality, shallow groundwater levels and biodiversity at representative south-west wetlands in relation to threatening processes (particularly dryland salinity and reduced rainfall) and 2) assessing the effectiveness of catchment and wetland management.

Progress

- Depth and water quality monitoring was undertaken at 104 wetlands, with data added to the SWWMP database and supplied to managers and researchers. Continuous water level recorders and tipping-bucket rain gauges were maintained on nine southern wetlands with high conservation values, especially for the Australasian Bittern *Botaurus poiciliptilus*, that are under threat.
- The 1977-2013 and 1977-2014 SWWMP reports were prepared, presenting depth, salinity and pH data for currently monitored SWWMP wetlands, with sections concerning recreational use, 'waterbird spectacles', threatened vertebrates and related matters.
- Final analysis of the relationships between water quality and quantity and aquatic fauna in the 25 biological monitoring sites was commenced.
- In the Drummond wetlands *Glacidorbis* snails were sampled across a season to investigate life-history in relation to the wetland's hydrological regime. Samples of aquatic invertebrates were collected and assessed against biodiversity targets in the Drummond Recovery Plan.
- The full 1997-2013 data sets for Vegetation and shallow groundwater monitoring have been compiled and quality assured. The full datasets will be archived in the data catalogue with suitable data including simplified trend summaries available on NatureMap.

Management implications

- Rainfalls and water levels in south-western Australia are declining and these trends have adverse consequences and long term implications for many species of wetland flora and fauna (such as the threatened Australasian Bittern) and for the recreational value of wetlands. Active management is required to ameliorate impacts and conserve threatened species.
- The SWWMP project provides warnings of these changes and helps inform where to focus management. Importantly, the long-term nature of this project provides a unique context against which to assess the significance of contemporary observations during decision-making processes and enables prediction of the effects of future changes due to catchment and wetland management and climate change.
- SWWMP data provides vital information for planning and assessing management interventions, such as the hydrological interventions to reduce water levels in the Warden (Esperance) Ramsar wetlands and management of depths for water skiing at Lake Towerinning.

Future directions

- Complete write-up of the 15 years of fauna and flora monitoring at the 25 intensively monitored wetlands and archive data.
- Continue to produce annual reports presenting the latest SWWMP data, trends and issues of concern and particular interest to wetland managers and researchers.
- Finalise report on thirty-year trends in rainfall and water levels of the more than 100 south-west wetlands of SWWMP.
- Undertake further statistical analysis of past and likely future trends in rainfall, water levels, salinities and pH.
- Use results of long-term periodic water level, salinity and pH monitoring, continuous on-site rainfall and water level monitoring and other datasets, to predict likely futures of wetlands important for the threatened Australasian Bittern and other fauna and flora in different climate scenarios, particularly continuing rainfall decline.
- More proactively communicate results and implications of SWWMP monitoring to other departmental organisational units and agencies with roles and responsibilities in the management of wetlands in south-western Australia.

- Develop a format to enable upload of vegetation monitoring data, including trends, to NatureMap.

SP 2015-001 Advancing the hydrological understanding of key Wheatbelt catchments and wetlands to inform adaptive management

Team

J Rutherford, L Bourke

Context

Changes in the hydrology of Toolibin Lake and the Lake Bryde catchments, due to land clearing, has resulted in these previously ephemeral fresh water wetlands developing a connection with deeper, saline groundwater and becoming degraded. A decline in average rainfall since the 1970s has seen a further decrease in wetland health as surface water flows and wetland hydroperiods decrease in quantity and quality. Robust management decisions require the main hydrological driver(s) of change to be identified and spatial and temporal fluxes (water and solutes) to be characterised. This project will significantly advance hydrological studies at Toolibin Lake and Lake Bryde by making full use of the data collection and analyses undertaken to date to produce practical tools for answering the key hydrological management questions.

Aims

- To produce quantitative conceptual hydrogeological model(s) for Toolibin Lake and Lake Bryde;
- To produce a numerical groundwater model to assess the Toolibin Lake water balance and determine the effectiveness of groundwater pumping (individual pumps) in returning the lake to a perched status;
- To evaluate catchment water and salt hydrodynamics (groundwater and surface water contributions/fluxes) tested using numerical modeling under different climate regimes (Toolibin Lake);
- To investigate the links between key ecological parameters (eg, tree and understory health, bird breeding, richness of aquatic invertebrates) and hydrological status (Toolibin Lake); and
- To produce risk assessment framework(s) to prioritise conservation actions and assess the transferability of research outcomes.

Progress

- Compiled and quality assured 20+ years of hydrological data;
- Assessed catchment-scale spatial and temporal trends against existing hydrogeological conceptual models;
- Provided the framework for the development of a rationalised, long-term hydrological monitoring programs; and
- Provided the basis for developing/iterating quantitative conceptual hydrogeological conceptual models.

Management implications

- The proposed activities, including numerical modelling, will provide a much firmer hydrogeological understanding of the threats to high conservation value assets associated within the DPaW estate in these catchments;
- The resulting tools will be used by managers to make decisions about how best to manage these wetlands, including maintaining, replacing or redesigning existing hydrology engineering infrastructure;
- This knowledge will be transferable to similar systems elsewhere in the region; and
- Archiving of Natural Diversity Recovery Catchment data on the Parks and Wildlife Data Catalogue will ensure that maximum value can be made of this high value resource into the future.

Future directions

- Designing a rationalised hydrological monitoring program (Bryde and Toolibin) for regional staff;
- Undertaking a wetland-scale investigation of the hydrology of Lake Bryde;
- Review and development of quantitative conceptual hydrogeological model for Lake Bryde and Toolibin Lake;
- Development of a numerical hydrogeological model for Toolibin Lake;
- Archiving of data to the Parks and Wildlife Data Catalogue; and
- Completion of six reports, summarised as Science Information Sheets, over period 2015-2017.

SP 2014-025 Taxonomy, zoogeography and conservation status of aquatic invertebrates

Team

A Pinder, K Quinlan

Context

The Wetlands Conservation Program undertakes research into aquatic invertebrate biodiversity, including spatial patterning and trends over time in relation to threats. Over half of the species we deal with are not formally described, but they are consistently named across departmental projects through maintenance of a voucher specimen collection. As opportunities and skills allow, program staff undertake systematics studies (primarily species descriptions and genetic analyses), sometimes with specialist co-authors. This allows formal naming and description of Western Australian endemics that would not otherwise occur and allows species to be consistently identified by external research groups. We also produce tools allowing consistent identification of aquatic invertebrates. This project encompasses this systematics research.

Aims

The aim of this project is to undertake research into aquatic invertebrate systematics to

- Better describe Western Australian aquatic invertebrate biodiversity.
- Allow more consistent identification of specimens by departmental and external researchers.

Progress

- *Glacidorbis* snails (which are very rare in Western Australia) from claypans in Drummond Nature Reserve were shown to be genetically distinct from *Glacidorbis occidentalis* Bunn and Stoddart 1983 from northern jarrah forest streams, reflecting the hydrological isolation of the Drummond wetlands.
- A paper describing a new species of *Boeckella* copepod from a claypan on Matuwa (ex Lorna Glen) was commenced.
- A paper was published on the genetic diversity of exotic earthworms in south-western Australia, showing that such earthworms have penetrated into some areas of native forests.

Management implications

- The genetic distinctness of the *Glacidorbis* snails adds to the already high conservation values of the Drummond Nature Reserve claypans and means that the continued existence of this genotype is dependent on adequately managing one claypan in a Natural Diversity Recovery Catchment (e.g. maintaining a seasonal hydrology and low salinity).
- The description of a new species of *Boeckella* copepod will allow consistent identification across the Goldfields region and therefore assist with environmental impact assessment.

- Exotic earthworms are entering some areas of native forests, either through natural dispersal from adjacent agricultural lands or mediated by human activities such as movement of forestry equipment.

Future directions

- Undertake similar taxonomic work as required and as resources allow.

SP 2014-024 Understanding peat wetland resilience: evaluating the impact of climate and land use change on the hydrodynamics and hydrogeochemistry of peat wetlands in the Warren (Muir-Byenup) District

Team

J Rutherford

Context

Peat wetlands are relatively rare in Western Australia but constitute an important habitat for biodiversity where they occur, especially in the far south-west of the State, providing refugia from seasonal and long-term drying for a range of restricted flora and fauna. Some peat wetlands in the Muir-Byenup Ramsar wetland suite are threatened by acidification and some have already acidified as a result of declining groundwater levels. Drying is also making these organic wetlands much more prone to catastrophic fires. The peat also stores a range of toxic metals and metalloids which are released to the environment as they dry. The major aim of this project is to undertake a risk assessment of fire susceptibility and release of acidity and other contaminants. The project will deliver a map of the distribution of at-risk peat wetlands, combined with recommendations for fire management and maintaining water balance.

Aims

- To determine current hydrogeological and hydrochemical conditions of four representative peat wetlands (eg water and chemical conditions and gradients)
- To map and quantify peat wetland carbon stores
- To identify and assess the transient behaviour of major threats to the health of the peat wetlands studied (eg role of drying climate and the source and mobility of acidity and salinity)

Progress

- Field work was undertaken in March to May to drill bores and collect augered samples of peat wetland sediment.
- Downhole Nuclear Magnetic Resonance Imaging was used to describe in-situ structure and composition of sediments.
- Laboratory analyses of substrate particle size, mineralogy and chemistry, isotopes and carbon dating were performed in various laboratories.
- Samples of peat were collected for an international collaboration examining peat microbial diversity around the world and analysed.

Management implications

- It is likely that small changes in the water balance make a significant difference to peat wetland health and this could be achieved through vegetation management
- Stores of organic carbon are significant to depths of ~1.5m and persist as wetland substrates dry. Understanding the spatial variability of carbon stores and rate of decline will assist in predicting fire risk.

Future directions

Priority research directions will include assessing wetland water balance dynamics that can maintain carbon store saturation and developing maps that identify wetlands, areas of wetlands where interventions may not be successful and assessment of fire risk is required.

SP 2014-023 Assessing and managing threats to flora in wetland communities

Team

M Smith, P Drake, M Drew, L Lewis

Context

Wetlands in the Wheatbelt conservation estate continue to be threatened by the consequences of altered hydrology, but the responses of many biological groups to these threats remains inadequately understood, limiting the design of management actions. This project encompasses ecological and ecohydrological research that aims to better understand responses of wetland flora to salinity and altered hydrology, particularly in the Natural Diversity Recovery Catchments. Knowledge gained will be of direct relevance to designing management responses to threats, including creating and implementing catchment and wetland recovery and management plans and other adaptive management programs.

Aims

- The overarching aim of this project is to investigate the responses of wetland flora to threatening processes and to use this to provide advice to managers on mitigation. Specific aims of work undertaken in 2014-15 were;
- To optimise inter-specific revegetation densities of *Melaleuca strobophylla* and *Casuarina obesa* on the bed of Lake Toolibin.
- To determine the upper salt threshold for the germination, survival and growth of *Melaleuca lateritia* in the Drummond Nature Reserve claypans.

Progress

- Field and glasshouse components of the *M. lateritia* project have been completed. Data is being analysed and a draft scientific paper is in preparation.
- The revegetation area of Lake Toolibin has been prepared, seedlings have been grown for planting, and the experimental design has been finalised.

Management implications

- The proposed work is designed to provide knowledge and interpretations to guide management of flora in ephemeral water bodies in important wetlands and their surrounds in the inland south-west of Western Australia. The knowledge gained from the proposed work will be broadly transferable to other wetlands.

Future directions

- Write the *M. lateritia* salinity tolerance experiments up as a scientific paper.
- At Lake Toolibin, plant seedlings in revegetation site and conduct post planting measurements (work to be undertaken by Wheatbelt Region).

SP 2011-018 Western Australian wetland fauna surveys

Team

A Pinder, M Smith, K Quinlan, R Coppen, L Lewis, Dr RJ Shiel (University of Adelaide)

Context

Regional biological surveys provide analyses of biodiversity patterning for conservation planning at broader scales, but sites in these projects are usually too sparse for use at a more local scale, such as individual reserves, catchments or wetland complexes. This umbrella project is designed to fill gaps within and between the regional surveys by providing aquatic invertebrate biodiversity data and analyses at finer scales. Past examples of such projects are surveys of wetlands in the Drummond, Warden and Bryde Natural Diversity Recovery Catchments, the Hutt River/Hutt Lagoon catchments and the mound springs near Three Springs. This project runs on an 'as-needed' basis.

Aims

- Provide understanding of aquatic biodiversity patterning at the scale of individual wetlands to wetland complexes and catchments to inform local conservation planning and as baselines for future monitoring.
- Provide better data on the distribution, ecological tolerances and conservation status of aquatic fauna species and communities.

Progress

- Processed samples of aquatic invertebrates collected in 2013 while sampling aquatic invertebrate biomass food resources for Western Swamp Tortoise.
- Prepared a paper on aquatic invertebrates of Goldfields wetlands sampled in 2014 following a rare summer rainfall event.
- Surveyed frogs, diatoms and fringing flora of wetlands in the Cervantes to Coolimba area as part of an offset provided by CSR Gyprock. Prepared a paper on the abiotic determinants of *Litoria moorei* (Amphibia) distribution.

Management implications

- In the Cervantes to Coolimba wetland system the survey of frogs and wetland flora will assist with assessment of proposals to expand gypsum mining and determining the ecological water requirements of groundwater dependent ecosystems.
- The survey of aquatic invertebrates in Goldfields wetlands fills a gap in knowledge of biodiversity in an area still subject to intensive mining, thus allowing more informed approvals decision making.
- On the Swan Coastal Plain, we have filled a data gap (aquatic invertebrates in seasonal vegetated clay-pans) that will allow more informed urban planning.

Future directions

- Publish paper on invertebrate diversity in vegetated claypans of south-west WA.
- Publish meta-analyses of WA arid zone invertebrate surveys.
- Expand the Cervantes-Coolimba wetland flora survey into dampland/palusplain wetland types.
- Undertake a survey of wetland biodiversity on Mulga Downs Station in collaboration with Rangelands NRM.
- Undertake survey of aquatic invertebrates in wetlands of the Walyarta portion of Mandora Marsh Ramsar wetland, to assess whether there has been any change over the last 20 years.

SP 2006-002 Monitoring stream biodiversity (KPI 20 of the Forest Management Plan)

Team

A Pinder, M Pennifold, J Williams

Context

Key performance indicator 20 of the Forest Management Plan 2004-2013 was the percentage of water bodies with significant variance of biodiversity from the historic range of variability. This was addressed by monitoring invertebrates in representative stream sites in the south-west forests, particularly in relation to forest management practices.

With the release of Forest Management Plan 2014-2023 a new project is being developed to address:

- KPI1 - *"Measurement and analysis of changes in spatial extent of healthy ecosystems and spatial extent of lower condition ecosystems from a current state."*
- KPI3 - *"Measurement and analysis of changes in spatial extent, vegetation condition, fauna communities and water quality of the (Ramsar) wetlands as a function of time and as defined by the relevant regional nature conservation plans".*

This project will address these KPIs by:

- Continuing to monitor a subset of higher condition streams from the KPI20 project to determine responses to declining rainfall and forest management.
- Re-surveying aquatic invertebrates in suites of important Warren Region wetlands (including the Muir-Byenup Ramsar wetlands) to quantify responses to changes in hydrology, water chemistry and other threats such as fire, over the last 10 to 20 years.

Aims

- Assess the condition of representative south-west forest streams (including in relation to forest management practices) by comparing the richness of aquatic invertebrates to that predicted by a previously constructed model (AusRivAS) developed using data from 'minimally disturbed' reference sites.
- Assess changes in invertebrate communities in key Warren Region wetlands (starting with the Muir-Byenup Ramsar wetlands) as a result of altered hydrology over the last decade and provide advice to regions on where to focus management activities.

Progress

- A journal article is being prepared in collaboration with scientists from CSIRO in Canberra: "Aquatic bioregionalisation derived from generalised dissimilarity models of compositional patterns in aquatic invertebrate fauna: an example from southwest Western Australia."
- Sampled aquatic invertebrates in Muir-Byenup wetlands in spring 2014 and summer 2015 and commenced processing these.

Management implications

- On the whole, there was no evidence that current forest management practices were having a significant effect on stream biodiversity, probably due, in part, to the practice of leaving unharvested buffers around streams.
- 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.
- A few stream sites were not in these categories and require further monitoring and investigation to examine the cause of the reduced diversity.

- The new work will allow the Warren Region to prioritise conservation efforts within the Muir-Byenup Ramsar wetlands by identifying those with lesser or greater resilience to change and those in higher or lower condition.

Future directions

- Re-sample streams in 2015, with a focus on those considered to be in minimally disturbed catchments, to provide long-term data on the response of aquatic invertebrate communities to declining rainfall (addresses KPI1 of the 2014-2023 FMP)
- Continue to update fire and logging history for catchment areas.
- Publish further papers examining impacts of declining rainfall and forest management practices on macroinvertebrate diversity in forest streams.
- Publish report with summaries of 10 year trends (2005 to 2015) for all stream monitoring sites.
- Develop new SPP to address KPI1 and KPI3 of the 2014-2023 FMP.
- Identify Muir-Byenup invertebrates collected in 2014/2015.
- Re-survey nationally important wetlands from south west previously sampled by Horwitz in 1997 (e.g. Owingup, Lake Jasper, Doggerup, Marringup, Mt Soho Swamp) and identified as priorities in the Warren Region Nature Conservation Plan.

Marine Science

Program Leader: Alan Kendrick

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

SP 2014-021 Habitat use, distribution and abundance of coastal dolphin species in the Pilbara

Team

R Douglas, H Raudino, C Severin, K Waples

Context

Australian snubfin (*Orcaella heinsohni*) and Australian humpback (*Sousa sahulensis*) dolphins inhabit Australia's north-western coastal waters, but little is known about the population sizes, distribution and residency patterns of these species. Current knowledge of these dolphin species in the Pilbara is currently poor and is limited to a dedicated study of humpback dolphins in Ningaloo Marine Park and Exmouth Gulf (Brown, *et al.* 2012) and opportunistic surveys and anecdotal sightings throughout the region (Allen, *et al.* 2012). Although the presence of several coastal dolphin species is expected in nearshore Pilbara waters (humpback, snubfin and bottlenose dolphins), very little is currently known of their residency, degree of use and habitat characteristics. Human pressures on these species are increasing in the Pilbara through activities associated with the rapid expansion of the resources sector, including oil and gas exploration and production, coastal infrastructure development and shipping. While this is a key factor that proponents are required to address to secure State

and Commonwealth environmental approvals, impact assessments for these species are complicated by the lack of best practice protocols and standards for survey design and data collection, which limits the comparison of different studies and study sites. This project will provide a better understanding of these species and their spatial and temporal use of Pilbara coastal waters and lead to greater certainty in assessing and managing impacts that relate to industrial developments. This project was designed to meet this priority need under the Wheatstone Offset C program.

Aims

This research is being conducted to develop a baseline understanding of key aspects of dolphin ecology in coastal Pilbara waters. The specific aims are to:

- Determine habitat use, distribution, abundance, residency, and movement patterns of dolphins in coastal Pilbara waters; and
- Identify the characteristics of habitats used by coastal dolphins, such as water depth, benthic substrate, timing and seasonal variation.

Progress

A three year research program has been initiated which will include both boat and aerial surveys each year. In this year we have:

- Developed a survey design and protocol for vessel based surveys in the impact area (Onslow) as well as other suspected high use areas for dolphins.
- Conducted two boat-based dolphin sampling trips (autumn and winter) based around Onslow. Data collected from these surveys will be used to estimate the abundance of coastal dolphin species in the area if the encounter rate is sufficient.
- Designed and conducted an aerial survey to cover coastal waters from Barrow island to Port Hedland and extending offshore to approximately the 20 metre bathymetry contour. Data collected from this survey will be used to produce an abundance estimate for the study area.
- Prepared the annual report for Chevron on Wheatstone Offset C.
- Developed a relationship with the Murujuga traditional owners to share information on dolphin sightings and important areas in the Dampier Archipelago as well as on survey protocols and data storage.

Management implications

The findings from this research will provide a baseline understanding of dolphin habitat use of the Pilbara region. This knowledge will inform the assessment of environmental impacts relating to future coastal developments and will assist to determine the conservation status of these species. Finally, the information establishes baseline data and monitoring protocols for long-term monitoring of these iconic species in State waters.

Future directions

This is the first year of a three year program. The designs for both vessel and aerial surveys are now established and these protocols will be used for three boat based surveys (autumn, winter and spring) and one aerial survey (autumn/winter) in each year of the program. Analyses will be undertaken of the resulting datasets to produce abundance estimates for at least two dolphin species (bottlenose and humpback dolphins) across the study area. Additionally, the survey data will be collated with other existing datasets to produce spatial habitat models of dolphin presence and relationships with key environmental factors across the Pilbara region.

SP 2014-018 Distribution and abundance estimate of Australian snubfin dolphins (*Orcaella heinsohni*) at a key site in the Kimberley region, Western Australia

Team

H Raudino, K Waples

Context

The current lack of knowledge of the Australian snubfin dolphin (*Orcaella heinsohni*) meant that its conservation status could not be properly assessed in 2011 due to insufficient information on population dynamics and distribution. This species is known from tropical coastal waters of Australia and New Guinea, but tend to be shy, evasive and difficult to study. Although they range southwards to the the Pilbara region of WA, there has been little WA-based research on this species and much of this remains unpublished. This project will compile existing data on snubfin dolphins across the Kimberley to gain a better understanding of their habitat use and distribution. The collation of data into a single database will also facilitate the study of population structure and demographics based on recognised individual animals. This project will assess dolphin distribution across the Kimberley region between 2004-2012.

This project was funded by a grant from the Australian Marine Mammal Centre and was undertaken in partnership with Dr Deborah Thiele (ANU) who provided the dolphin survey data and Dr Philip Bouchet (UWA) who provided data analysis expertise. A number of indigenous sea ranger groups in the Kimberley participated in dolphin surveys and are providing input to the associated broad-scale habitat use mapping.

Aims

This project will use existing data to:

- 1) Provide a quantitative abundance estimate of snubfin dolphins for Roebuck Bay in WA that will be used as a baseline for this population and will also enable comparison with abundance estimates of the species from sites at Cleveland Bay (Qld) and Port Essington (NT).
- 2) Compare methods for abundance estimation (mark-recapture versus distance sampling) and the suitability of these methods for abundance estimation of this species.
- 3) Map the extent of occurrence and area of occupancy of snubfin dolphins in the Kimberley by combining traditional knowledge and dolphin sightings from indigenous sea rangers and scientific survey sightings.
- 4) Refine and populate a purpose built and standardised database which will support long term data collection and curation in WA and facilitate data-sharing between jurisdictions.

Progress

The research project was mostly completed this year with ongoing activities related to manuscript preparation and submission due for completion in the latter half of 2015. The major activities for this year include:

- Development and modification of the DolFin Database to meet WA data input needs.
- Entry of all dolphin photo-identification and survey data for Roebuck Bay into the DolFin Database.
- Analyses of survey data from 2009 to produce abundance estimates of dolphins using Roebuck Bay during a five month survey period using mark-recapture methodology and distance sampling methodology for comparison.
- Analysis and compilation of a broad-scale distribution map showing extent of occurrence and area of occupancy, as defined by IUCN guidelines.
- Preparation and submission of the final report to the Australian Marine Mammal Centre.
- Preparation of two draft journal papers for peer-review publication.
- Presentation of the database, data collection and data entry processes to the Yawuru sea ranger group so that they can use the DolFin database for their ongoing monitoring data collection and storage.

Management implications

This research project has brought together scientific and traditional knowledge of a poorly understand marine mammal species of high conservation value. The implications and relevance for management are:

- A baseline abundance estimate for snubfin dolphins in the proposed Yawuru Nagulagun / Roebuck Bay Marine Park.
- A database has been established that will continue to be used and maintained by Parks and Wildlife for all dolphin research and monitoring where survey and photo-identification data is collected. The database ensures data is available in a standardised format useful for assessing population abundance and distribution. It also provides the capacity to develop sighting histories for individual animals, thus providing a better understanding of population demographics and life history.
- The database also can be used for information sharing across jurisdictions and between research organisations.
- The broad-scale collation of information and modeling has provided relevant information on area of occupancy and extent of occurrence that can be used to more accurately assess the conservation status of this species.
- Partnerships have been established with indigenous sea ranger groups to develop survey methodologies, data storage and reporting structures that are consistent with healthy country plans and park joint management plans.

Future directions

Two peer-reviewed journal papers, which are both in final draft stage, will be submitted for publication based on this research. They are:

Cross-cultural knowledge informs the distribution of the Australian snubfin dolphin (*Orcaella heinsohni*) in the Kimberley, Western Australia. (For submission to *Endangered Species Research*).

Population estimate of the Australian snubfin dolphin (*Orcaella heinsohni*) Roebuck Bay, Western Australia. (For submission to *Biological Conservation*)

The dolphin survey database that has been established will continue to be used by the Department for all current and future dolphin survey research and monitoring.

A research grant application has been made that will facilitate extending the database to include dolphin survey data from other parts of the Kimberley.

SP 2014-005 Access and human use at Penguin Island and related implications for management of Marine Park assets and visitor risk

Team

K Friedman, G Shedrawi

Context

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

Aims

- Establish a system for recording beach arrivals of nesting little penguins, and high risk crossings by visitors to Penguin Island;

- Determine social and environmental factors that characterise periods of high use of the sand bar crossing; and
- Provide information to assist in the development and implementation of new and existing mitigation strategies that minimises visitor risk.

Progress

- Implemented a department-hosted web application facilitating the analysis of infrared recordings of little penguin beach arrivals by department staff and community volunteers.
- Enabled Parks and Wildlife staff to view near real-time video footage of people crossing the sandbar spit between Mersey Point and Penguin Island.
- Implemented the automated remote conversion, upload and corporate storage of video footage of both Little Penguin beach arrivals and visitor sandbar crossings.
- Determined the proportion of Penguin Island visitors using the sandbar as an access route as opposed to the ferry service during 2014-15.
- Identified peak periods and environmental conditions when visitors are using the sandbar as an access point to Penguin Island and characterised the different user groups that were making high risk crossings.
- Summarised data and preliminary findings collected during 2014-15 and presented this information to Swan Coastal District.

Management implications

Marine park managers now have an improved understanding of the numbers of Little Penguins landing on two major beaches during the breeding season which can be used to document trends in abundance. This new remote monitoring tool facilitates 'condition' and 'pressure' assessments of little penguins. This information is used to adapt on-ground management and to support reporting to the MPRA and the broader community.

The monitoring tool allows managers to target visitor risk mitigation strategies aimed at decreasing high risk crossings to Penguin Island. The preliminary information provided to managers indicates that management intervention strategies such as sandbar closures and signage may lower the proportion of visitors using the sandbar to access Penguin Island and indicates the relative value of patrols by Surf Life Saving Association life guards.

Future directions

- Collect penguin beach return information to inform managers of penguin breeding activity;
- Collect data on visitor high risk sandbar crossings at Penguin Island for 2015-16;
- Improve the camera system to increase resolution of imagery; and
- Research further options that engender greater community engagement.

SP 2014-004 Improving the understanding of West Pilbara marine habitats and associated taxa: their connectivity and recovery potential following natural and human induced disturbance

Team

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

Context

The focus of work for Wheatstone development Project B will be to add to the understanding of west Pilbara marine habitats (including coral and seagrass communities) and associated taxa, including their level of connectivity and their recovery potential should they be impacted by natural and human induced disturbance. This

research aims to build on existing knowledge and integrate with current and proposed connectivity projects on habitat-forming taxa and associated taxa in the tropical north-west of Australia. Broad-scale connectivity studies of flora and fauna within and between the offshore islands of the north-west continental shelf have shown varying levels of connectivity. Previous studies have also shown limited connectivity between inshore and offshore marine communities but there have been no studies looking at connectivity and recovery potential between locations within the Pilbara region, and their connections with the broader inshore locations of Ningaloo to the south-west, and the Kimberley to the north-east.

Aims

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

Progress

- Completed sample collections from Montebello Islands, Shark Bay, Dampier Archipelago, Balla Balla, Onslow, Exmouth Gulf, Broome and part of Ningaloo Reef.
- Deployed and collected the second year of coral recruitment settlement tiles for the temporal study of recruitment processes in the Onslow region.
- A second in-situ assessment of recruit corals on reefs in the Onslow region using quadrats with underwater visual census and digital photos was completed.
- Preliminary planning for the coral recruitment study was completed.
- Analysis was undertaken of pre-dredging benthic images provided by Chevron to understand the size-class frequency distribution of corals in the Onslow region.
- DNA extractions for mangroves, seagrass and fish were commenced.

Management implications

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

Future directions

- Finalise collecting tissue samples of organisms and processing of tissue samples for genetic analysis (connectivity study).
- Continue lab work for connectivity study including, extracting DNA, sending off for sequencing, analysing data and manuscript preparation.
- Begin analysing genetic data.
- Analyse second year of data on settlement of corals.
- Analysing benthic images from 'during dredge operations' period for coral demographics assessment and reporting.
- Redeploy coral settlement tiles in February and May 2016 to determine settlement differentials across the period of spawning.

SP 2013-006 The influence of macroalgal fields on coral reef fish

Team

S Wilson, T Holmes

Context

Macroalgae are a prominent component of tropical benthic communities along the north-west coast of Australia. Within the Ningaloo Reef lagoon, large fields of macroalgae are a distinct feature of the marine park, covering ~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 Marine Park, and determine the relative importance of physical and biological drivers of algal abundance and diversity.
- Identify attributes of macroalgal fields favoured by juvenile fish and examine the relative importance of habitat quality and predation on juvenile abundance.
- Assess influence of juvenile fish on replenishment and future adult abundance.

Progress

- A manuscript on importance of macroalgal fields for herbivorous and predatory fish has been published in *Marine Biology*.
- Work on seasonal fluxes in macroalgal biomass and the importance of tropical macroalgae as habitat for fish has been presented as seminars to the Pilbara research workshop, Darwin initiative Chagos, NOAA Coral Reef Ecosystems Division Hawaii and in presentations to Parks and Wildlife staff at Exmouth District.
- The Honours project (STP 2014-007) examining diet and habitat affiliations of a nominally herbivorous fish was completed and the findings have been submitted for publication in a peer reviewed journal.
- Field data for three summers and three winters has now been collected.

Management implications

- Improved understanding of the spatial arrangement of macroalgal fields that increase our ability to predict distribution of algal biomass and diversity for spatial planning across marine parks.
- Surveys of macroalgal communities offer a baseline for future monitoring, evaluation and reporting of condition change in macroalgal communities.
- Assessments of how abundance and biodiversity of fish recruits relates to the characteristics of macroalgal fields improves our understanding of which habitat features promote recruitment, a process that supports both ecological (fish communities) and social values articulated in the Ningaloo Marine Park Management Plan and management plans for other tropical marine protected areas. Knowledge of this fish algal relationship may improve our ability to predict future abundance of adult fish stock, particularly those threatened by changes in habitat, climate and fishing pressure.

Future directions

- Compile and analyse all seasonal data to address the above objectives.
- Write up for publication and present findings in regional meetings, workshops and at scientific conferences.

SP 2013-002 Understanding movements and identifying important habitats of sea turtles in Western Australia**Team**

S Whiting

Context

This project will use satellite telemetry to track turtles that are released to the wild with minimal and extensive rehabilitation. These turtles will be small juveniles with a preferred habitat thought to be off the continental shelf in the open ocean and large juveniles and adults that largely prefer continental shelf habitat including inshore areas. The tracking results will identify the geographic range and preferred habitats and provide insight into the viability and survivorship of healthy and rehabilitated turtles in the wild. The identification of preferred habitat will allow pressures to be identified and prioritised for these size classes. As tracking results will be broadcast live on the internet (updated daily via seaturtle.org) it will provide a link between Parks and Wildlife science activities and the community. The genetic information (derived from samples collected routinely across a range of projects) will provide another layer of information that will help to describe the spatial range of juvenile turtles Western Australia

Aims

- Determine the distribution and movement of sea turtles, particularly juveniles;
- Investigate how components of sea turtle biology (including genetics) influence turtle distribution (including preferred sites), movement and foraging ranges;
- Investigate how environmental drivers, such as oceanographic factors, influence turtle distribution (including preferred sites), movement and foraging ranges; and
- Investigate the viability and survivorship of rehabilitated turtles

Progress

Eight neonate flatback turtles were tracked from Eighty Mile Beach as part of a collaboration with Florida Atlantic University, the Aquarium of Western Australia and James Cook University. Turtle hatchlings were collected from Eighty Mile Beach and flown to Perth where they were raised until they were large enough to carry a transmitter. Once over 300 g they were flown to Broome, attached with transmitters and release inside the Eighty Mile Beach Marine Park. Results will be available later in 2015.

Management implications

This tracking of neonate flatback turtles will provide the first information on the dispersal characteristics of this species. The data can be used statewide but also it provides specific habitat information that can be used to assist management of Eighty Mile Beach Marine Park.

Future directions

This project will continue to track rehabilitated turtles upon their release and analyse and publish the data that is generated.

SP 2012-008 The Western Australian Marine Monitoring Program (WAMMP)

Team

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

Context

A state-wide system of marine protected areas is being established in WA as part of Australia's National Representative System of Marine Protected Areas. Long-term monitoring of the condition of environmental assets and social values is recognised as an integral aspect of adaptive management. The Department's Western Australian Marine Monitoring Program is a State-wide, long-term, marine monitoring, evaluation and reporting program that is being developed and implemented to increase the efficiency and effectiveness of marine reserve and threatened marine fauna conservation and management.

Aims

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

Progress

- Measurement of asset condition, related pressure and (management) response information for multiple biophysical assets and social values (e.g. finfish, coral, seagrass, macroalgae, mangrove, penguins, turtles, little penguin, cetaceans, water quality, visitor participation and risk) were undertaken across twelve marine reserves extending from Walpole Nornalup Inlets Marine Park in the south to Lalang-garram / Camden Sound Marine Park in the north.
- Twelve Annual Marine Protected Area Biodiversity Assets and Social Values Reports that include updated time-series information on multiple biophysical assets and social values were delivered to marine park managers to assist adaptive management planning and delivery, and to inform MPRA audit reporting.
- Collaborated with PVS and RFMS staff on a project to determine how to monitor 'seascapes', which are a social value in ten marine reserve management plans.
- Implementation of improved data storage, information management and reporting processes for long-term time-series monitoring data.
- Provided an assessment of seagrass condition to the Cockburn Sound Management Council and assistance to two industry groups and the Commonwealth environmental agency in relation to coral community condition assessments.
- Trained Departmental staff, interns and volunteers on monitoring protocols for ecological assets such as coral, fish, seagrass, mangroves and little penguins.

Management implications

Long-term monitoring datasets provide a means of learning from past management experience and improving service delivery, the 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 rigorous scientific evidence.

Future directions

- Continued design and implementation of bio-physical asset, social and cultural value monitoring for the new Lalang-garram Camden Sound, Eighty-Mile Beach and Ngari Capes marine parks.
- 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 WA's marine parks and reserves and threatened marine fauna.
- Continue to increase the focus of monitoring, evaluation and reporting on social values, anthropogenic pressures and stakeholder participation.

SP 2012-007 Review, assess and summarise historical data relevant to the management of the proposed Dampier Archipelago Marine Park and Regnard Marine Management Area

Team

K Friedman, M Mohring, 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 volumes of marine environmental and social data have been collected by various agencies, institutions and companies in this area since the late 1970s. This project will collate and review these 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 historical time-series from data that is relevant to the conservation of marine ecological assets and social values in the Dampier Archipelago area.
- Ensure that the data identified in this review is summarised, archived and made accessible where possible to government, industry and the broader community.
- Assist the design and implementation of Pluto LNG Project Offset “d” projects (ii), (iii) and (iv).

Progress

- An assessment of historical data relevant to the management of the proposed Dampier Archipelago Marine Park and Regnard Marine Management Area was completed, with a Pluto Offset ‘d’ Project ‘i’ final report lodged in November 2014.
- The final project report included information on over 800 datasets relating to 14 ecological values.
- The final project report describes a number of key project achievements in addition to historical descriptions of marine asset and related pressure information, including i) a guideline for context setting, prospecting, data mining and reporting of historical datasets, ii) the design and implementation of innovative information management solutions for information storage and distribution, and iii) delivery of information to assist the development of other Pluto offset ‘d’ projects.

Management implications

Understanding the effectiveness of current and past management relies on an ability to identify potential changes to asset condition over time. Access to historical data provides such an opportunity, with improved understanding of historical trends for environmental assets and social values helping to inform time-series baselines. Making historical trends in the condition of marine assets and human use of this region visible to today's managers, recognises and capitalises on past investment in science, helping to speed up the process of identifying existing and potential issues that may require management action.

Future directions

- The final report for Pluto Offset 'D' Project 'i' has now been completed.
- The Western Australian Marine Monitoring Program (SPP 2012-008) and other Pluto LNG Project Offset "D" projects will seek to gain access to the remaining high-priority datasets identified by the project to assist on-going monitoring and research in the proposed Dampier Archipelago marine reserves.

CF 2011-118 North West Shelf Flatback Turtle Conservation Program strategic plan

Team

S Whiting, T Tucker

Context

The North West Shelf Flatback Turtle Conservation Program (NWSFTCP) is one of four environmental additional undertakings for the Gorgon Gas project at Barrow Island. The purpose of the 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.

Progress

In the past year a range of projects outlined in the draft Strategic Conservation Plan progressed or were initiated and included:

- thermal studies on embryonic development;
- preliminary data collected on fox impact on clutches of eggs at Mundabullangana Station;
- nesting sites were mapped across the Kimberley as part of the WAMSI Turtle project;
- neonate flatback turtles were tracked using solar powered GPS transmitters;
- hosted the 2nd Australian and 2nd Western Australia Symposia;
- the NWSFTCP Advisory Committee met twice and reviewed budgets and reports.

Management implications

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

Future directions

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

CF 2011-117 WAMSI 2: Kimberley Marine Research Program

Team

K Waples, S Field

Context

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

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

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

Aims

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

Progress

- Project agreements are now in place for 24 of the 25 projects. One project is being re-scoped to ensure it best captures traditional owner knowledge, values and needs.

- Engagement with relevant traditional owner groups is ongoing. A formal Research Agreement has been signed between Dambimangari PBC and WAMSI with Schedules covering 9 projects. Two other Indigenous groups are working towards accepting the same Research Agreement.
- Field research has been completed for three of the projects and is underway for a further 10 projects. Six of these projects have included participation by Traditional Owners on field work.
- Relationships have been established and fostered with the IPA Coordinators for Dambimangari and Bardi Jawi and the Healthy Country officer of Wunambal Gaamberra to assist with Indigenous engagement and the practicalities of working on country with sea ranger groups.
- Milestone reports have been received, reviewed and approved for 12 projects.
- A workshop was held with 6 participating indigenous communities in September 14 to develop an agreed way forward for the Indigenous Knowledge project. This workshop culminated in development of an SCP, later approved by the R&D Committee and in the formation of a working group to continue to progress the project. The working group has had several follow on meetings and is in the process of nominating a Project Leader and assessing several EOIs for technical assistance to the project.
- A communication strategy has been drafted and relevant communication activities underway.
- A plan and process for knowledge transfer and uptake is being implemented including the development of a synthesis reporting framework and the formation of a Knowledge Uptake Advisory Committee.
- Two workshops have been held with key stakeholder groups (DPAW planners and DPAW Kimberley region) to discuss the research program, manager needs and expectations for outputs that can be readily translated into management outcomes. Engagement is ongoing with these key stakeholders groups.
- A series of topic specific workshops have been coordinated to develop better information sharing between projects and to capitalise on shared opportunities. These have included bathymetry, modelling, LiDAR and Indigenous information needs.
- Update meetings have been held with Dambimangari, Bardi Jawi and Wunambal Gaamberra PBCs to discuss WAMSI and the KMRP research projects relevant to their country. There has been an ongoing dialogue between these groups, the Node Leadership and relevant project leaders as well as with the KLC regarding project progress and Research Agreement(s).
- Two Science Review sessions have been held, evaluating 8 KMRP projects in total. All actions arising from these reviews have been undertaken.
- All projects have been encouraged to engage with media when in the Kimberley and a rapport has been established with Broome ABC. Several projects have been aired on the radio, including an overview of WAMSI, human use patterns and turtles.
-

Management implications

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

Future directions

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

SP 2011-003 Spatial variation in the functional morphology of mangroves in the Shark Bay World Heritage Area**Team**

M Rule, A Kendrick, J Huisman

Context

None

Aims

None

Progress

None

Management implications

None

Future directions

None

SP 2010-008 Effects of the Gorgon Project dredging program on the marine biodiversity of the Montebello/Barrow Islands marine protected areas**Team**

S Field, RD Evans, K Friedman, G Shedrawi

Context

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

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

Aims

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

Progress

Progress has continued on writing the Gorgon MER report, which describes potential impacts of marine construction on bio-physical assets. All chapters have now been internally reviewed.

A pilot study to examine the utility of identifying coral disease from digital images was carried out.

Management implications

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

Future directions

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

SP 2009-013 Spatial and temporal patterns in benthic invertebrate communities of the Walpole and Nornalup Inlets Marine Park

Team

A Kendrick, M Rule

Context

None

Aims

None

Progress

None

Management implications

None

Future directions

None

SP 2009-003 Interactive effects of fishing and climate change on coral reef fish populations**Team**

S Wilson, T Holmes

Context

Climate change and over-fishing are widely regarded as the major threats facing coral reef communities world-wide. 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.

Progress

- Using data collected from 21 reefs the condition of coral and fish was monitored over 17 years to assess impacts and recovery from a climate driven disturbance. Analyses found shallow water reefs with low levels of structural complexity had undergone a phase shift to now be dominated by macroalgae, while coral reefs in water deeper than 6m and with moderate levels of structural complexity were more likely to recover. *Graham et al. 2015. Predicting climate-driven regime shifts versus rebound potential in coral reefs. Nature 518: 94-97.*

- A book chapter summarizing both the direct and indirect effects of climate change on coral reef fish was published. *Pratchett et al. 2015 Effects of climate change on coral reef fishes. In (Mora ed.) Ecology of Fishes on Coral Reefs.*
- A workshop on the effects of climate change on seagrass communities was attended and a manuscript is being prepared for publication.

Management implications

Environmental disturbances associated with climate change pose a major threat to the long term condition of coral reef ecosystems. Understanding which environmental factors promote recovery on coral reefs allows managers to identify which reefs are more likely to persist over time. Our work has identified two metrics, depth and structural complexity, which can be easily measured over large spatial scales to locate reefs resilient to disturbances like coral bleaching. This information will help conservation planners determine which areas are most appropriate for protection when designing marine parks.

Future directions

The influence of range shifts of tropical fish into temperate waters will be examined.

SP 2009-002 Spatial and temporal patterns in the structure of intertidal reef communities in the marine parks of south-western Australia

Team

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

Aims

- Determine the spatial and temporal patterns in the composition of intertidal reef communities in the MMP, SIMP and NCMP, including the proposed northern extension to the SIMP (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 in the development of methods for long-term monitoring of intertidal communities in temperate marine reserves.

Progress

- A paper detailing the intertidal reef invertebrates from Marmion and Shoalwater Islands marine parks was published in *Conservation Science Western Australia*. This paper described the relative distribution and abundance of 71 species of primarily molluscs and echinoderms from rocky intertidal platforms in the MMP and SIMP. Most of the species had a temperate distribution that extends across southern Australia and few were primarily tropical (at the southern limits of their distribution in the study area). Twelve species are endemic to WA.
- A Lansdscope article was published which concerned the temperate gastropod *Campanile symbolicum*
- A paper describing spatial patterns in the intertidal invertebrate communities of the MMP and SIMP is in preparation.
- A draft photographic species identification guide to assist future monitoring of temperate intertidal reefs has been completed and is being reviewed.
- Fifteen intertidal reef sites were surveyed at Ngari Capes Marine Park.

Management implications

This is the first comprehensive spatial and temporal study of the biological communities associated with intertidal reefs of Western Australia's temperate marine parks and reserves. The fauna have a predominantly temperate distribution around southern Australia. Several species have a tropical affinity and are at their southern limit of distribution in sw WA. The results of this work provide a baseline understanding of intertidal reef 'condition' in the marine parks in relation to natural processes and possible anthropogenic impacts, and will assist the implementation of long-term intertidal reef monitoring, and management and conservation of their value across Western Australia's temperate marine parks and reserves.

Future directions

- Ecological papers from data collected in MMP and SIMP will be published.
- The species identification guide to assist future intertidal reef monitoring in MMP and SIMP will be completed.
- Intertidal reef surveys at Ngari Capes Marine Park will continue.

Ecoinformatics

Program Leader: Colin Yates

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

CF 2011-108 Provision of authoritative names of Western Australian taxa

Team

P Gioia, A Chapman

Context

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

Aims

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

Progress

- Support for automation of a hard copy census, and associated data cleaning, was completed.
- Minor bugs have been fixed and enhancements implemented as required.

Management implications

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

Future directions

- Commence planning to migrate WACensus from Oracle Forms architecture to a better supported environment that can integrate with Australian Plant Census and Atlas of Living Australia online services.
- Annually publish a hard copy of the Census of Western Australian Plants.
- Smut names are scheduled to be implemented within the 2015/16 financial year.

CF 2011-106 Online GIS biodiversity mapping (NatureMap)

Team

P Gioia

Context

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

Aims

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

Progress

- A new version of NatureMap based on current technology was deployed in August, 2014. The new version runs on a much faster server, enabling users to more effectively perform large queries.
- The fire ecology component of the Great Western Woodlands theme was updated with a summary of findings.
- Many new datasets were added. In particular, over twenty years of aquatic survey data from over twenty projects was added to the repository.
- Occurrence records now total 3.4 million, an increase of 207,840 (6%).
- The number of datasets warehoused has increased from 42 to 61 (45%).
- NatureMap recorded 205 new registrations over the last twelve months, bringing the total from 1748 to 1953, a 12% increase.

Management implications

- NatureMap provides a long-term repository for conserving and protecting the department's digital biodiversity data assets, so that knowledge can continue to be informed and improved through staff succession.
- NatureMap significantly reduces the time spent searching for point-based biodiversity data as well as easing the process of generating species lists for any area in the state.

Future directions

- Continue incorporation of new and historical survey data into NatureMap.
- Integration with the new proof-of-concept BioSys biological survey database.
- A new Rangelands theme is scheduled for implementation.

Student Projects

STP 2012-202 Parasites and diet of feral cats and rodents on mainland Western Australia and offshore Islands (Christmas Island and Dirk Hartog Island)

DPaW Scientists

D Algar

Students

N Dybing (PhD)

University Academics

Dr P Adams

Progress Report

Overall, a total of 66 cats (30 male and 36 female) and 101 rats (47 males, 53 females and one not recorded) collected from Christmas Island have been necropsied and samples collected for further testing. A high prevalence of parasitic infection was found in these hosts with greater than 84% of both cats and rats found to be harbouring at least one parasite species and up to six (for cats) and seven (for rats) different parasite species (total infracommunity richness, ICR). Overall, 18 different helminth genera were represented, with a local richness of 10 species identified in cats (representing four Phyla; Nematoda, Cestoda, Trematoda, and Acanthocephala) and 12 species identified in rats (three Phyla; Nematoda, Cestoda, and Acanthocephala). The local richness and total infracommunity richness found in this study is higher than expected. This is due to the island syndrome which dictates that island communities should typically have a high prevalence but a low richness of parasite species due to the founder effect. However this study has found an unusually high local and infracommunity richness, the reasons of which are still to be elucidated.

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

STP 2014-016 The ecology and interactions of dingoes and feral cats in the arid Rangelands of Western Australia

DPaW Scientists

N Burrows

Students

M Wysong (PhD)

University Academics

Prof R Hobbs (University of Western Australia), Dr E Ritchie (Melbourne University)

Progress Report

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

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

The current phase of research for the project seeks to investigate fine-scale habitat use and diets of these two species to better understand their extent of spatial and dietary overlap. At present, we have deployed 136 camera traps across three major habitat types. This study will run for 21 days prior to the annual Eradicat baiting and again for 21 days starting two weeks after the baiting. An occupancy modelling approach will be used to analyse this data and will help us understand habitat use of dingoes and feral cats and how this habitat use is impacted by baiting.

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

Preliminary analysis of movement data indicates that dingoes and feral cats maintain some spatial separation from each other and use different habitats. This PhD thesis is now being written up and will be submitted for examination in February 2016.

STP 2014-017 Investigation of taxonomic boundaries in the *Tetratheca hirsuta* Lindl. complex

DPaW Scientists

R Butcher, K Thiele, M Byrne

Students

E Joyce (BSc (Honours))

University Academics

Prof P Grierson (The University of Western Australia)

Progress Report

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

STP 2016-001 Vegetation responses to Noongar land management practices in old and young landscapes

DPaW Scientists

M Byrne

Students

None (PhD)

University Academics

None

Progress Report

None

STP 2012-211 Ancient, terrestrial islands in a semi-arid landscape: patterns of genetic diversity in regional endemics of the Yilgarn Banded Iron Formations

DPaW Scientists

M Byrne, D Coates

Students

H Nistelberger (PhD)

University Academics

Dr D Roberts

Progress Report

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

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

STP 2015-010 Assessment of hybrid status and conservation significance of intermediate populations within the *Stylidium caricifolium* complex (Stylidiaceae) in southwest Western Australia

DPaW Scientists

D Coates, K Thiele

Students

L Craft (BSc (Honours))

University Academics

Prof L Mucina (The University of Western Australia)

Progress Report

This project aims to assess the evolutionary consequences and conservation significance of hybridization between *Stylidium affine* and *S. caricifolium*. While both species are widespread and common and do not require specific conservation efforts certain intermediate populations may need to be considered for listing as Priority Flora if found to represent a stable hybrid derived species. Specifically this project will assess if there are morphological patterns in flower shape and differences in ecological features that distinguish the two parental

taxa and the hybrids, and utilise molecular genetic markers to confirm the hybrid status of putative hybrids and whether any populations show evidence for independent evolutionary divergence representing a separate hybrid derived species. To date the molecular genetic data indicates that there are a geographically discrete group of populations that may represent a separate hybrid derived taxon and that there is also clear genetic structure within both putative parental species.

STP 2012-222 Factors that affect seedling establishment and the implications for the translocation of species at risk of extinction

DPaW Scientists

D Coates

Students

C Allen (PhD)

University Academics

A/Prof P Poot, A/Prof M Moody (The University of Western Australia), A/Prof R Standish

Progress Report

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

STP 2013-055 Trypanosomes of some Western Australian mammals: phylogenetics

DPaW Scientists

A Friend

Students

J Austen (PhD)

University Academics

Dr U Ryan

Progress Report

Characterisation of Australian native trypanosomes has detected a high prevalence of *T. copemani* affecting quokka populations at both Two Peoples Bay (91.4%-32/35) and Bald Island (85.3% 29/34) and now for the first time recent research as part of this PhD has identified *T. copemani* in two quokka isolates from Rottnest Island. Given that the main cause of animal trypanosomiasis is haemolytic anaemia, the detection of trypanosomes on Rottnest may account for the unknown cause of seasonal anaemia and low red blood cell counts previously reported in quokkas from the Island. Further clinical investigations are needed to determine the clinical impact of *T. copemani* on quokka populations but preliminary findings show erythrocyte abnormalities associated with haemolytic anaemias, in trypanosome infected quokkas. In addition to *T. copemani*, a novel *Trypanosoma* sp. genetically similar to a kangaroo isolate H25, previously reported to be closely related to *T. cruzi*, was identified in one quokka, while another quokka isolate had mixed infections of both *T. copemani* and *T. vegrandis* and is the first report of *T. vegrandis* in quokkas. In depth morphological analysis using light microscopy, immunofluorescence, scanning electron microscopy and fluorescent *in situ* hybridisation has identified, a promastigote, amastigote and sphaeromastigote stages *in vivo*, as well as novel trypanosome life-cycle stages, representing an oval stage, an extremely thin stage and an adherent stage. Interesting the adherent stage represented by a small rounded independently rapid moving form or a form found on the surface of erythrocytes may have the potential to cause erythrocyte destruction, consequently leading to both erythrophagocytosis and haemolytic anaemia, a common feature of trypanosomiasis, with the exact cause unknown. This study shows that trypomastigotes are not the only trypanosome life-cycle stage present within the blood stream of Australian marsupials. The absent of the true blood stream trypomastigotes stage and low parasitemia may account for the previous lack of detection of trypanosomes on Rottnest Island, given that only sphaeromastigote and amastigote stage were observed. The importance of understanding all the life-cycle stages of Australian trypanosomes is important when considering clinical diagnosis, false negatives in epidemiological studies and preventing disease outbreaks.

The above findings have now been written up and have finalised my PhD which was submitted on the 2.7.15 and is currently under examination.

STP 2013-056 Systematics of *Sargassum*(Phaeophyceae) in Australia

DPaW Scientists

J Huisman

Students

R Dixon (PhD)

University Academics

J Huisman

Progress Report

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

All aspects of the project have been completed and Rainbo Dixon has submitted her Ph.D. thesis, which has been passed pending minor corrections.

STP 2013-057 Molecular taxonomy, phylogeography and population genetics of the *Grevillea thelemanniana* complex**DPaW Scientists**

G Keighery

Students

T Hevroy (PhD)

University Academics

A/Prof M Moody (The University of Western Australia), Dr S Krauss (Botanic Gardens and Parks Authority)

Progress Report

Project and PhD completed.

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

STP 2012-216 Feeding ecology of Pomacentridae and its ecological role in fish herbivory in temperate algal-dominated reefs**DPaW Scientists**

A Kendrick

Students

F Vitelli (PhD)

University Academics

A/Prof G Hyndes

Progress Report

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

Parma mccullochi was found to be a strict herbivore, feeding almost entirely on foliose and filamentous red algae and the diets of juvenile and adult fish did not differ. Electivity indices indicated that *P. mccullochi* specifically

selected these algae. Macroalgae differed significantly inside and outside *P. mccullochi* territories and a caging experiment in territories indicated a moderate effect on the composition of recruiting algae.

This thesis has successfully passed examination. The outcomes of the research have been published as Vitelli F, Hyndes GA, Kendrick AJ, Turco A (2015) Turf-forming algal assemblages on temperate reefs are strongly influenced by the territorial herbivorous fish *Parma mccullochi* (Pomacentridae). *Marine Ecology Progress Series* **523**, 175-185.

STP 2012-217 The role of *Kyphosus* spp. in reef ecosystems

DPaW Scientists

A Kendrick

Students

A Turco (PhD)

University Academics

A/Prof G Hyndes

Progress Report

Field studies in Marmion and Ningaloo marine parks have now been completed, as have pilot studies on how to best survey kyphosids and assess their diets. A quantitative study of habitat use has been completed and all fishes required for laboratory work in the study have been collected. Dietary data and habitat has been analysed and chapters on habitat associations and diet of different species are being written.

STP 2012-218 Fire weather

DPaW Scientists

L McCaw

Students

M Peace (PhD)

University Academics

Dr T Mattner, Dr G Mills, Dr J Keppert

Progress Report

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

can be tested. Case studies include forest and shrubland fires in southern Australia. A detailed technical report examining significant aspects of the behaviour of the Kangaroo Island bushfires of December 2007 has been published. A case study of unexpectedly severe fire behaviour during a prescribed burn in October 2010 at Layman block east of Margaret River was published in the *Australian Meteorological and Oceanographic Journal*.

The WRF model has been used to investigate the effect of coupling between the fire and the atmosphere. This has been done by simulating the growth of well-documented fires with and without the coupling function in the WRF model being enabled. Clear differences in fire behaviour have been observed between these contrasting model runs, and differences are consistent with known fire behaviour phenomena. A paper describing simulations of the 2007 D'Estrees fire was published in the *Journal of Applied Meteorology and Climatology*. A manuscript describing simulations of the Layman prescribed burn and has been accepted by the *Australian Meteorological and Oceanographic Journal*, and a further manuscript is in review. The PhD thesis was accepted by the University of Adelaide in December 2014.

STP 2012-220 Factors affecting fauna translocation success

DPaW Scientists

K Morris

Students

J Dunlop (PhD)

University Academics

Prof A Thompson (Murdoch University)

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. vegrans*. Ectoparasites were identified to species level to determine whether there has been a change in species diversity in the new environment, and to determine the effectiveness of the antiparasitic treatment. Presence of these trypanosomes and ectoparasites were added to models of survivorship to determine if there was a relationship, as well as to follow the pattern of infection across the population. Skeletal and mass measurements, body condition and fecundity of golden bandicoots released at Lorna Glen and Hermite Island were compared to long-term monitoring data from the source population. Upon establishment at both new sites, translocated males increased in condition (i.e. body mass but not skeletal size) and females showed an increased reproductive output. Bandicoots born at translocation sites were significantly larger and heavier ($P < 0.0001$ and $P < 0.0001$ respectively) than the founders from the island population within 18 months of establishment. This change in skeletal size, mass and fecundity took place in a single generation at both mainland

and island translocation sites, suggesting that the response is not one of evolution by natural selection. This study demonstrated that the small size of golden bandicoots on Barrow Island is not a genotypic response to selective pressures, but rather a phenotypic response to conditions on the island. When translocated to vacant ecological niches, they have the capacity to produce offspring with increased body mass, size and reproductive output. We suggest that ecological processes relating to resource limitation drive 'island dwarfism' in *I. auratus*. This PhD study has been completed and the thesis is being prepared.

STP 2013-060 Ecology and taxonomic differentiation in the Australian water rat and implications for its conservation status in Western Australia

DPaW Scientists

K Morris

Students

K Bettink (PhD)

University Academics

Dr H Mills

Progress Report

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

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

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

This PhD has been completed and the thesis submitted for examination in August 2015.

STP 2012-221 Genetic consequences of mammal translocations in Western Australia using case studies of diboobies, boobies and black-flanked rock wallabies

DPaW Scientists

K Morris

Students

R Thavornkanlapachai (PhD)

University Academics

Dr H Mills

Progress Report

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

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

The animals for the dibbler translocation to Escape Island were sourced from populations on Boullanger and Whitlock islands that are genetically distinct and have slightly different body sizes. Genetic analysis show evidence of genetic mixing which started from the captive bred colony and continued in the Escape population. However, the mixing seemed to bias toward the Boullanger ancestor, and appears to be size related. Females were observed to preferred heavier males. A low effective population size of approximately eight dibblers was estimated from the genotypic data. Morphological comparisons between different offspring groups, after taking gender differences into account, showed no significant differences except for the head length. However, the sample size was small. Population viability analysis suggested the Escape population will persist for another 70 years. A supplementation as low as seven pairs of dibblers every 10 years can prolong population's persistence. Investigation of a burrowing bettong translocation to where animals were derived from two genetically and morphologically distinct source populations, Barrow Island and Dorre Island, showed evidence of genetic mixing. The new population had higher genetic diversity in both nuclear and mitochondrial DNA than its parental populations. However, the results suggested a genetic bias toward larger Dryandra bettongs. Based on mtDNA, 70% of interbred offspring were born from Dryandra mothers and Barrow Island fathers. This suggested that the uneven founder proportion from each source population may influence the genetic bias. Offspring morphology showed a positive relationship between the offspring body size and the parental genetic percentage, where the interbred offspring were larger than expected.

The laboratory work and data analyses have been completed, and thesis drafted. It is anticipated that the PhD thesis will be submitted for examination in August 2015.

STP 2013-013 Nutrient movement and its impact on aquatic invertebrates as a food source of waterbirds between different wetland suites within the Lake Warden Wetland System**DPaW Scientists**

A Pinder

Students

J Lizamore (PhD)

University Academics

Dr R Vogwill (The University of Western Australia)

Progress Report

Due to a reduction in resources allocated to the Lake Warden Natural Diversity Recovery Catchment the scope of the project was changed from a numerical orientated hydrological and geochemical model of wetland suites to a simpler one focusing on specific lakes.

During 2014/15 additional literature was surveyed to reflect the changed nature of the project and fortnightly monitoring (aquatic invertebrates, waterbirds and water chemistry where possible) of six hyper-saline lakes was completed: Lake Warden, Pink Lake, White Lake, Lake Benje Benjemup, Lake Hanson 1 and Lake Hanson 3. Monthly monitoring of Lake Hiller was undertaken over the same period. Aquatic invertebrate samples are now being processed with funding from South Coast NRM.

At least three papers are planned:

- A simplified numerical model of water balance and solute load differences between Pink Lake and Lake Warden.
- A study of the feasibility of reinstating the surface water hydrological link between the two lakes as part of long term restoration plans.
- Managing increased salt loads in Lake Warden and its impacts on aquatic invertebrate assemblages as food source for waterbird assemblages.

STP 2015-013 Diversity in the *Triodia basedowii* E.Pritz. species complex and its implications for the evolution of the Australian arid zone biota

DPaW Scientists

K Thiele

Students

B Anderson (PhD)

University Academics

Progress Report

The *Triodia basedowii* species complex is widespread across arid Australia, with a centre of diversity in the Pilbara bioregion. It includes a number of undescribed (phrase-named) species of uncertain taxonomic status. This project is using morphological and genetic data (sequencing of molecular and chloroplast markers as well as Next Generation approaches) to understand taxonomic and phylogeographic patterns in the *T. basedowii* species complex. Results will allow a better understanding of taxa in the complex, the recognition and delimitation of a range of new taxa, improved understanding of the role of hybridisation in this important Australian grass genus, and an insight into the evolution of the flora and vegetation of arid zone Australia

STP 2015-012 Phylogeny, systematics and evolution of the Australian arid-zone *Ptilotus*

DPaW Scientists

K Thiele

Students

(PhD)

University Academics

Progress Report

The mulla mulla genus *Ptilotus* is an important and often spectacular component of the vegetation in much of arid Australia, especially in the Pilbara, and is one of the largest arid-zone genera in Australia. Some species of *Ptilotus* have a remarkable ability to uptake large quantities of phosphorus (P) without apparently suffering effects of P-toxicity at levels that would be fatal to other plants. This project builds on a successful Masters project that produced the first robust framework phylogeny for the genus, and aims to:

- complete the *Ptilotus* phylogeny including all remaining species
- gain an understanding of the evolution of the genus and of its close relatives (*Aerva*, *Omegandra*, and *Kel-lita*), including their evolution both before and after the ancestors of *Ptilotus* reached Australia from east Africa
- gain an understanding of the role that mobilisation and uptake of phosphorus plays in the ecological success of *Ptilotus*, and of the evolution of key elements of phosphorus metabolism in *Ptilotus*
- use *Ptilotus* as a model genus for understanding the radiation of key plant genera in arid Australia since the Miocene transition of the Australian continent from mesic to arid conditions

STP 2015-011 Are *Banksia* species changing in response to a drying climate? An investigation of potential range contraction and leaf indices of stress

DPaW Scientists

K Thiele

Students

(PhD)

University Academics

Progress Report

The south-west of WA has experienced substantial climate change in the last several decades, particularly a significant reduction in winter rainfall since the 1970s. Modelling suggests that *Banksia* species, like many other WA plants, are susceptible to adverse impacts from climate change, including local extinctions at climate-stressed ends of the range resulting in range contractions and/or shifts. This study seeks to determine whether observable range-contraction has occurred since the 1970s in a range of common *Banksia* species, using data from the citizen science *Banksia* Atlas project and a contemporary citizen science project using volunteers to revisit targeted *Banksia* Atlas sites. It also seeks to measure stress-related parameters in *Banksia* leaves, to assess the likely causes of any observed range contractions

STP 2012-224 Regional variability in salmon gum communities in the Great Western Woodlands

DPaW Scientists

S van Leeuwen

Students

J Harvey (MSc)

University Academics

Dr R Harris, Prof L Mucina (The University of Western Australia), Dr S Prober (CSIRO)

Progress Report

This project aimed to determine if there is regional variation in the understorey of *Eucalyptus salmonophloia* woodlands across the Great Western Woodlands (GWW) and, if so, what environmental factors were influencing it. The project then integrated relevant existing survey data from across the Wheatbelt to assess the variation across the two bioregions in which salmon gum woodlands occur, Avon-Wheatbelt and Coolgardie. This project fills large gaps in the floristic surveys of the GWW, which have previously focused on the banded ironstone and greenstone ranges. One hundred sites were sampled in spring 2011 and 2012, in old growth woodlands or woodlands where the timber cutting and/or grazing history could be estimated. Data was collected on species composition, cover and height, tree dimensions, site-based variables, and soil physical and chemical characteristics. Detailed classification and ordination of the data revealed two main communities; one with an understorey of mainly chenopod species on soils higher in clay found in the drier north and east of the GWW, and the other with non-chenopod species (e.g. *Eremophila* spp., *Acacia* spp., *Scaevola spinescens* and *Alyxia buxifolia*) found on sandier soils in the wetter south and west. Precipitation, monthly precipitation variability and temperature, and to a lesser extent soil phosphorous, pH, silt content, and cover of organic crust influenced the patterns in floristic composition and differentiated between the two main communities. When data from the Wheatbelt was incorporated the two GWW communities remained prominent and were joined by two Wheatbelt communities and one community (with *Melaleuca pauperiflora*) that traversed the two regions. Across this larger area the influence of the annual precipitation gradient and ratio of summer to winter rainfall (less in the east) was strong. Generally regional factors (such as climate) were more influential on the floristic patterns than local (such as soil) factors. This project has contributed to knowledge about these woodlands relevant to their conservation status, delineation of subregional boundaries and land management activities. The salmon gum - chenopod shrublands burn less frequently as they are less flammable and have a more sparse cover than the salmon gum - eremophila woodlands which are experiencing fire more frequently and consequently being reduced in extent. Vouchers for all species collected will be lodged in the Perth Herbarium and the field data will be lodged with TERN-OS.

STP 2012-225 Ecological study of the quokka (*Setonix brachyurus*) in the southern forests of south-west Western Australia**DPaW Scientists**

A Wayne

Students

K Bain (PhD)

University Academics

A/Prof R Bencini

Progress Report

This project aims to: i) determine if a reliable estimate of quokka abundance can be obtained from indicators of activity including scats, tracks and runnels; ii) identify the preferred habitat of quokka in southern forests; iii)

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

Home range and movement patterns have been investigated using 29 collared quokkas and results indicate a mean home range of 71ha (core range 18ha) with movements averaging between 0.4 and 2.4km/night. Largest movements were recorded in summer and autumn and were linked to requirements to forage further afield for water and food during hot dry conditions. Collared animals spent 40% of their time in riparian habitat within a stable home range and emigrating individuals travelled distances of up to 14.2km, using riparian vegetation as corridors. Forest areas with fire treatment and comparable unburnt sites have been examined for quokka abundance and habitat quality pre- and post-fire to determine the effect of fire on habitat use and the time taken for habitat to become re-colonised post-fire. DNA has been provided to staff at Murdoch University, who will be assisting with DNA processing. A paper presenting an effective and efficient survey method for quokka has been published.

STP 2012-230 Wildlife ecology in the southern jarrah forest

DPaW Scientists

A Wayne

Students

G Yeatman (PhD)

University Academics

Dr H Mills

Progress Report

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

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

Yeatman, Georgina J., and Adrian F. Wayne. "Seasonal home range and habitat use of a critically endangered marsupial (*Bettongia penicillata ogilbyi*) inside and outside a predator-proof sanctuary." *Australian Mammalogy* (2015).

STP 2013-019 Diversity of trypanosomes infecting Western Australian marsupials: virulence and pathogenicity

DPaW Scientists

A Wayne

Students

A Botero (PhD)

University Academics

Prof A Thompson (Murdoch University)

Progress Report

The kinetoplast is an organelle that is present in all trypanosomatids. It contains a giant network of thousands of catenated circular DNAs (kDNA) with unique structure and function. kDNA consist of a few dozen maxicircles that encode mitochondrial gene products, and several thousand minicircles that encode guide RNAs for the editing of mitochondrial RNA transcripts. Minicircles have been extensively used in the development of sensitive and specific diagnostic molecular tools due to their abundance and heterogeneity in size and sequence between species. They contain a 12-nucleotide-sequence named "The Universal Minicircle Sequence" (UMS) that is conserved within most trypanosomatids. The number of UMS elements and their location in each minicircle differ between species. Our results report novel insights into the kinetoplast structure and kDNA organisation of *Trypanosoma copemani*, a parasite associated with the drastic decline of the Australian marsupial *Bettongia penicillata*. Transmission electron microscopy images showed classical disk-shaped kDNA network morphology, similar to that seen in late-emerging trypanosomatids such as *T. cruzi*, *T. brucei* and *C. fasciculata*. PCR, sequencing, and Western blot analysis showed the presence of the UMS elements in the minicircles of *T. copemani* and the existence of the UMS-Binding Protein (UMSBP), which is also present in all trypanosomatids and is involved in minicircles replication. Sequences obtained from the minicircles of *T. copemani* G1 and *T. copemani* G2 strains revealed significant similarities with the minicircles of *T. cruzi*.

This research was presented at the Australian Society for Parasitology Conference in Canberra 2014 and was awarded with the prize for the best Poster presentation.

STP 2013-016 A comparative health and disease investigation in the woylie: captive vs free-range enclosure vs wild

DPaW Scientists

A Wayne

Students

K Skogvold (PhD)

University Academics

Dr K Warren, Dr S Vitali, Dr C Holyoake, Dr C Monaghan

Progress Report

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

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

STP 2014-012 An exploration of the associations between the population decline of *Bettongia penicillata ogilbyi* (Gray, 1837) and field health assessment data from the Upper Warren region Western Australia

DPaW Scientists

A Wayne

Students

M Pleitner (BSc (Honours))

University Academics

Dr D Mahsberg

Progress Report

This independent student project (part of Honours) investigated possible associations between the population decline of the critically endangered woylie and the skin and fur conditions found on some individuals. Some woylies show skin alterations accompanied by fur loss. The causes for these changes remain unclear. Data from Keninup, Upper Warren Region between 2006 and 2012 was evaluated. Gender-related differences were unverifiable. Mean body mass increased over time but it was not able to investigate possible correlations between the changes in body mass and skin and fur symptoms.

STP 2012-226 Ectoparasites of threatened mammals in Western Australia: biodiversity and impact

DPaW Scientists

A Wayne

Students

H Burmej (PhD)

University Academics

Prof A Thompson (Murdoch University), Dr A Smith

Progress Report

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

STP 2015-014 Validating management options for maximising genetic “success” in translocation programs for the Woylie (*Bettongia penicillata ogilbyi*)

DPaW Scientists

A Wayne

Students

A Atkinson (PhD)

University Academics

Dr C Pacioni (Murdoch University), Dr P Spencer (Murdoch University)

Progress Report

The aim of this thesis was to explore and validate management options for increasing genetic diversity in translocated populations. Specifically, the effectiveness of founder selection and population supplementation was assessed, using the critically endangered woylie (*Bettongia penicillata ogilbyi*) as a model species. The woylie has a complex conservation history, and is currently undergoing an unexplained decline. The establishment of insurance populations is an important conservation strategy for this species and presents a valuable opportunity for testing and measuring translocation strategies.

Using genetic data, this study determined that the genetic diversity of a founding population could be more efficiently captured using a spatially-designed sampling regime. Tested against conventional grid and transect trapping methods, the species-specific model returned animals that were less related, and therefore more genetically appropriate, for establishing a translocated population.

Population models were developed to forecast the genetic diversity of two translocated woylie populations, before and after population supplementation. Genetic data was then used to assess the efficacy of the modelling projections and determine whether or not supplementation was effective at maintaining genetic diversity over time. The population models were shown to over-estimate diversity in both instances, with only a modest increase in one population, and a decrease in the other. These results indicate that the animals used in supplementation were reproductively ineffective, or simply did not survive long enough to contribute genetically to the population.

The results of this study have real implications for the ongoing management of real woylie populations, and highlight the value of genetic monitoring in translocations. Additionally, this work makes a valuable contribution to the burgeoning science of reintroduction biology, by providing much needed empirical evidence into the effectiveness of two genetic management strategies.

STP 2014-008 Investigating the impact of polyparasitism in translocated woylies (*Bettongia penicillata*), and the effect of anti-parasite treatment on host fitness and survivability.**DPaW Scientists**

A Wayne

Students

A Northover (PhD)

University Academics

Prof A Thompson (Murdoch University)

Progress Report

This project is currently evaluating how fauna translocations impact the transmission of parasites in woylies (*Bettongia penicillata*), and what consequences this has for translocated hosts and other cohabiting species (Brush-tail possum - *Trichosurus vulpecula*; Chuditch - *Dasyurus geoffroii*). We are testing the hypothesis that fauna translocations lead to a higher diversity of parasites within the resultant host-parasite community, and thus a higher incidence of polyparasitism; which in conjunction with the disruption of established host-parasite associations, may exacerbate the negative impacts of parasites on their hosts to the detriment of translocation success. Secondly, as the effects of anti-parasite treatment in translocated hosts are relatively unknown; we are also assessing the effect of parasite removal in translocated hosts. We are testing the hypothesis that anti-parasite treatment reduces the incidence of polyparasitism, thereby improving host fitness and survivability. In June 2014, 182 woylies were translocated from Perup Sanctuary to two unfenced sites within Western Australia. In June 2015, an additional 69 woylies were translocated into Dryandra Woodland; a second spatially independent study site. Pre- and post-translocation, woylies from both the source and destination sites were measured and weighed, and pouch activity was recorded for females. Blood, ectoparasite and faecal samples were also collected for parasitological examination. In each destination site, cohabiting species were sampled to quantify parasite transmission between species post-translocation. To evaluate the effect of anti-parasite treatment, we treated half the woylies with Ivermectin prior to translocation. We have observed changes to the predominant species of *Trypanosoma* in woylies pre- and post-translocation, and that anti-parasite treatment has had an effect on both target and non-target parasites of the translocated hosts.

STP 2013-015 Trypanosome polyparasitism and the decline of the critically endangered Australian potoroid, the brush-tailed bettong (*Bettongia penicillata*)**DPaW Scientists**

A Wayne

Students

C Thompson (PhD)

University Academics

Prof A Thompson (Murdoch University)

Progress Report

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

The PhD thesis

STP 2014-010 Stress and disease in critically endangered woylies (*Bettongia penicillata*)

DPaW Scientists

A Wayne

Students

S Hing (PhD)

University Academics

Prof A Thompson (Murdoch University), Dr S Godfrey (Murdoch University)

Progress Report

While much is known about effects of stress on immunity and infection in domestic animals and humans, these links are rarely examined in wildlife. This is concerning because wildlife face many stressors such as habitat loss and predators. We aim to investigate effects of stress on immunity and infection in critically endangered woylies. In conjunction with DPAW and other collaborators, we conducted intensive fieldwork in sanctuaries, reserves and the wild. So far, >500 faecal samples have been analysed for stress hormones, 300 for parasite eggs and over 200 blood samples for parasite DNA. In addition, we adapted a test developed in pre-term human infants to evaluate woylie immunity. Analyses are underway to investigate how these measures vary in relation to experimental stressors, management interventions (reserve expansion and translocation) and natural disaster (bushfire). In this way, we will have a comprehensive picture of stress, immunity and infection in the context of *in situ* and *ex situ* wildlife conservation.

STP 2012-229 The role of *Toxoplasma gondii* in declining populations of the woylie (*Bettongia penicillata ogilbyi*)

DPaW Scientists

A Wayne

Students

A Worth (PhD)

University Academics

Prof A Thompson (Murdoch University), A/Prof A Lymbery, Dr T Fleming

Progress Report

The aim of this study is to increase understanding of the role of the protozoan parasite *Toxoplasma gondii* in wild woylie populations, particularly with regard to the recent population declines. *T. gondii* can infect virtually any warm-blooded vertebrate, and has a worldwide distribution. In asymptomatic laboratory and wild rodents, *T. gondii* is reported to cause changes in behaviour that may make infected hosts more susceptible to predation. If *T. gondii* alters the behaviour of woylies, this could predispose infected individuals to predation and increase mortality rates, thus contributing towards the decline of woylie populations. Serum samples collected by Department of Parks and Wildlife staff between 2008-2010 have been analysed to determine *T. gondii* infection status based on presence or absence of antibodies. Testing of these samples revealed a very low sero-prevalence (~5%) of *T. gondii* antibodies in woylies, which is in agreement with work by previous students. Due to this low sero-prevalence, it has been difficult to investigate whether *T. gondii* affects woylie behaviour. This outcome will be ongoing and is likely to be descriptive rather than statistical. Testing of longitudinal serum samples in the current project has revealed that sero-diagnosis is complicated, and false negatives may be common. This has important implications for wildlife disease monitoring that relies on serology. In conjunction with the woylie project, we have also investigated mouse behaviour in response to experimental *T. gondii* infection; particularly behaviours related to activity level, anxiety behaviour and cat urine avoidance behaviour. In contrast to many other studies, we found limited evidence for *T. gondii*-induced behavioural changes in mice. Three posters and one oral presentation have been presented on this work at conferences. Two scientific journal articles concerning the effect of *T. gondii* on rodent host behaviour have been published so far.

STP 2014-009 Pathogen transmission in the critically endangered woylie: a community, population, and individual approach**DPaW Scientists**

A Wayne

Students

K Jones (PhD)

University Academics

Prof A Thompson (Murdoch University), Dr S Godfrey (Murdoch University)

Progress Report

Infectious pathogens may play a role the recent decline of the woylie; thus, characterising factors influencing pathogen transmission is a priority of this project. Woylies in a predator-proofed reserve, Whiteman Park, are fitted with GPS collars to monitor movements; social network analysis will be used to develop networks that reflect potential transmission pathways for refuge-based or environmental pathogens. Screening for pathogens while assessing health, reproduction, and behavioural attributes will allow assessment of risk factors and potential fitness effects of pathogens in isolation or combination. Furthermore, network transmission models can facilitate the identification of behavioural (e.g., connectedness) or demographic (e.g., sex) factors key to pathogen propagation.

Fieldwork continued this year across multiple seasons, with completion expected in January 2016. Preliminary laboratory work has begun. An unexpected fire at the site in December 2014 also introduced a new component to the study –the effects of fire on woylie movements, social networks, and parasites.

STP 2013-018 Genetic diversity of *Blastocystis* isolates found in West Australian native fauna

DPaW Scientists

A Wayne

Students

U Parkar (PhD)

University Academics

Prof A Thompson (Murdoch University)

Progress Report

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

STP 2014-011 Histopathological review of the causes of death in Woylies (*Bettongia penicillata*) presented to Murdoch University for necropsy in the last 10 years, with special focus on (possible) *Trypanosoma* related histopathology.

DPaW Scientists

A Wayne

Students

Z Lim (PhD)

University Academics

Prof A Thompson (Murdoch University), Dr S Godfrey (Murdoch University)

Progress Report

The aim of this project is to review the causes of deaths and histopathology in the Woylies presented to Murdoch University in the last 10 years; particularly the presence of Trypanosomes, their related histopathology and their significance. Two of 73 Woylies had organisms (morphologically similar to Trypanosomes) associated with muscle lesions in oesophagus and heart. These lesions may have resulted in decreased food intake and abnormal function of the heart respectively, possibly contributing to death. This project will also attempt to identify the Trypanosomes and demonstrate spatial association between Trypanosoma DNA and muscle (or other) lesions via in-situ hybridization (ISH). In light of the study by Botero and others (2013), an increased understanding of the effects of Trypanosoma infections in the Woylie will help aid future management of this species. Our database collates post-mortem results from woylies, including tissues examined (and findings) and archived tissues. The database is complete and is being reviewed and collated. A probe to identify a conserved region of Trypanosome kinetoplast DNA has been designed and purchased; and labeling efficiency tests will start July 2015.

STP 2014-013 Optimal release locations and timing for rehabilitated sea turtles using a decision support system**DPaW Scientists**

S Whiting

Students

N Robson (BSc (Honours))

University Academics

Dr M Thums, Dr C Pattiaratchi

Progress Report

This project aimed to identify the most suitable locations and months to release rehabilitated turtles along the Western Australian coast. The project was completed in 2014/15 with the submission of an honours thesis. This project used ocean models and theoretical particle tracking to produce a decision support tool to assist managers to select the best locations and times to release rehabilitated turtles. This ensures that individual turtles that have had many hours of community care have the best chance of survival. A manuscript is in preparation.

STP 2013-072 Assessing the resilience of marine turtle embryos to extreme temperatures**DPaW Scientists**

S Whiting

Students

J Stubbs (PhD)

University Academics

Dr N Mitchell (University of Western Australia)

Progress Report

This project investigated the effect of temperature on turtle reproduction at Cape Domett beach in the eastern Kimberley. The project is now completed. The major findings of this project included the determination of a pivotal temperature (the incubation temperature at which 50% male and 50% female young are produced) for a winter/dry season nesting population of flatback turtles and the development of predictive climate models based on measured and hind-cast data. The results have been published in a peer-reviewed journal.

STP 2014-014 Predicting the effect of climate change on embryonic flatback (*Natator depressus*) and green (*Chelonia mydas*) sea turtles in the Kimberley region of Western Australia**DPaW Scientists**

S Whiting

Students

B Bentley (BSc (Honours))

University Academics

Dr N Mitchell (University of Western Australia), Dr J Kennington, Dr O Berry

Progress Report

This project is part of the WAMSI Kimberley Node Turtle Project, and will investigate climate change impacts on turtle nesting using prediction and hind-casting models. In 2014/15 this project successfully deployed weather stations in three remote locations in the Kimberley and retrieved eggs from two remote sites for incubation in Perth. The incubation experiments were successful although data are not fully analysed.

STP 2012-233 Assessing the resilience of marine turtle embryos to extreme temperatures**DPaW Scientists**

S Whiting

Students

J Tedeschi (PhD)

University Academics

Dr N Mitchell (University of Western Australia), Dr O Berry, Dr M Meekan

Progress Report

This project was designed to investigate the resilience of sea turtles in relation to climate change. A PhD thesis was submitted in 2015. Major results of the project revealed two heat shock proteins that are useful for assessing heat stress with variance related to geography and maternal and paternal genetic variance. Genetic variance may also play a major role in thermal tolerance. Two manuscripts have been published with a third currently in review.

STP 2012-235 Variation in the intensity of periodic harvests in Fijian tabu areas and the effect on reef fish assemblages**DPaW Scientists**

S Wilson

Students

J Goetze (PhD)

University Academics

Dr T Langlois (University of Western Australia)

Progress Report

Field work on this project is now completed.

A manuscript assessing which survey techniques best detected impacts of harvesting has been published in the Journal of Experimental Marine Biology and Ecology. The paper demonstrates that diver operated stereo video were more effective at detecting the effects of harvesting on fish assemblages than underwater visual census by divers or baited underwater video. These results were presented to the Parks and Wildlife Marine Science group, the International Marine Conservation Council (Scotland) and Oceans Institute student group. A workshop on meta-analyses of periodic harvest data occurred in January 2015. Results are currently being prepared for publication.

STP 2014-007 How does a seaweed-associated reef fish respond to seasonal habitat loss?**DPaW Scientists**

S Wilson

Students

I Lim (BSc (Honours))

University Academics

Dr C Fulton

Progress Report

Field work for this project has been completed. The student has submitted her thesis and been awarded first class Honours. A manuscript based on the thesis has been submitted for publication in a peer reviewed international journal. The manuscript demonstrates that fish associate with macroalgal patches that have a high canopy and persist in patches where canopy height and cover are maintained over the winter. This is consistent with previous work that indicates that to protect macroalgal associated fish communities macroalgal fields that maintain their structure throughout the year should be given greater conservation status.

STP 2015-003 Can diver operated stereo-video surveys of fish be used to collect meaningful data on tropical coral reef communities for long term monitoring?**DPaW Scientists**

S Wilson, G Shedrawi

Students

K Bennett (PhD)

University Academics

Dr T Langlois (University of Western Australia)

Progress Report

Monitoring methods for one asset often collect information relevant to other natural assets. Use of a single method to monitor the condition of multiple assets can reduce operational costs of a monitoring program, although it is important that the method does not compromise manager's ability to detect signals of change in biological indicators. This study investigated comparability of benthic community data recorded by downwards facing cameras, commonly used in benthic monitoring programs, and a forward facing stereo-DOV (F-DOV) typically used in fish surveys. Analyses indicated a degree of similarity in the benthic taxa detected by the two digital imagery methods; however the forward facing stereo F-DOV video systems demonstrated an enhanced ability to describe erect benthic components of the reef, and limited ability to detect benthos with low morphological profiles in comparison to downwards facing cameras. Using comparative models, data recorded by one method can be adjusted and corrected to make it comparable with the data collected by the alternative method. Thus, Stereo-DOV surveys for fish can be considered a suitable method for the simultaneous assessment of fish and important benthic habitat. In conjunction with imagery collected using downwards facing cameras Stereo-DOV imagery may also provide a more extensive and cost effective description of the benthic marine environment through space and time.

A honours thesis related to this project has been submitted.

Tables

Table 1: Major plant groups in the Herbarium's collection

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