

Department of Parks and Wildlife

Science and Conservation Division

annual research report

2015–16



Department of
Parks and Wildlife



Acknowledgments

This report was prepared by the Science and Conservation Division of the Department of Parks and Wildlife.

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Images

Front cover: Fortescue River, Pilbara *Photo – Keith Morris / Parks and Wildlife*

Inset: Coral monitoring at Shark Bay *Photo – Mike Rule / Parks and Wildlife;*

Tephrosia sp. Carnarvon *Photo – Ryonen Butcher / Parks and Wildlife;*

Gilbert's potoroo *Photo – Dick Walker / Gilbert's Potoroo Action Group*

Back cover: Sampling in wetland on Ethel Station *Photo Mike Lyons / Parks and Wildlife*

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Department of
Parks and Wildlife



Director's Message

The past year has been one of consolidation after a period when we reviewed our activities and identified the core functions science is required to deliver to support government priorities. We have continued to implement our Strategic Plan to integrate science into the delivery of the Department's strategic goals of wildlife management, parks management, forest management, and managed use of natural assets. Our resources and activities are aligned with our core functions to ensure we are delivering best practice science driven by management priorities to inform effective conservation.

Through 2015-16 we continued our work in the core areas of 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. Some highlights of activities this year have been the launch of books documenting the outcomes of the Kimberley Islands Survey and the Pilbara Biological Survey; development of a Population Viability Analysis for Carnaby's cockatoo; knowledge to support recovery actions for threatened animals, birds and plants affected by the severe fires along the south coast in 2015; establishing a survey database to ensure effective management of plot based data; review of the marine monitoring program to direct resources to the most effective outcomes and rationalise the reporting framework; and reconstruction of the major fires affecting WA in the past twelve months.

Support for Biodiversity and Marine Science as one of the State Government's five science priorities continues. The Western Australian Biodiversity Science Institute (WABSI) was launched by the Premier in October 2015 as a joint venture between nine founding partners, including the Department of Parks and Wildlife. The Governing council and Board are guiding its establishment, with an Executive Director in place and two Node Leaders appointed for the Biodiversity Survey, and Biodiversity Processes and Threats Nodes. Node Leaders for the Information Management, and Restoration and Ex-situ Conservation Nodes are being sought. I look forward to engagement of the Division in all of the nodes as the institute develops and with all relevant partners in delivering the agreed research plan for each node.

Our partnership with WAMSI continues and many projects under the Kimberley Marine Research program are now in the knowledge exchange phase. A series of seminars and meetings with managers and end-users were delivered to help understand the implications of the research outputs for marine park management.

It is pleasing to see major engagement of divisional staff with three hubs of the National Environmental Science Program (NESP), the Threatened Species Hub, the Northern Australian Environmental Resources Hub and the Marine Science Hub. The NESP hubs are strongly aligned with our own objectives as they seek to deliver applied research to support on-ground management; hence the involvement of our staff provides a key perspective on the application of excellent science to address conservation and management issues.

This year has seen a national focus on threatened species following the Threatened Species Summit where the Threatened Species Commissioner released the Threatened Species Strategy. Many of the target species for the strategy are found in Western Australia and our research on the biology and ecology of these species and their threats is critical to making a difference in conservation management outcomes. Many of our scientists were involved in the Threatened Species Forum coordinated by the Northern Agricultural Catchment Council and held in Geraldton to highlight the conservation management of threatened species in Western Australia.

As we continue to deliver excellent science to underpin effective biodiversity conservation in Western Australia, I encourage you all to make the most of opportunities and continue to seek innovative ways of delivering science to support the Department's core functions.

I welcome our continued engagement with all our partners, both within the Department and externally, in the 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 embrace our natural heritage.

Dr Margaret Byrne
Director Science and Conservation
July 2016

Contents

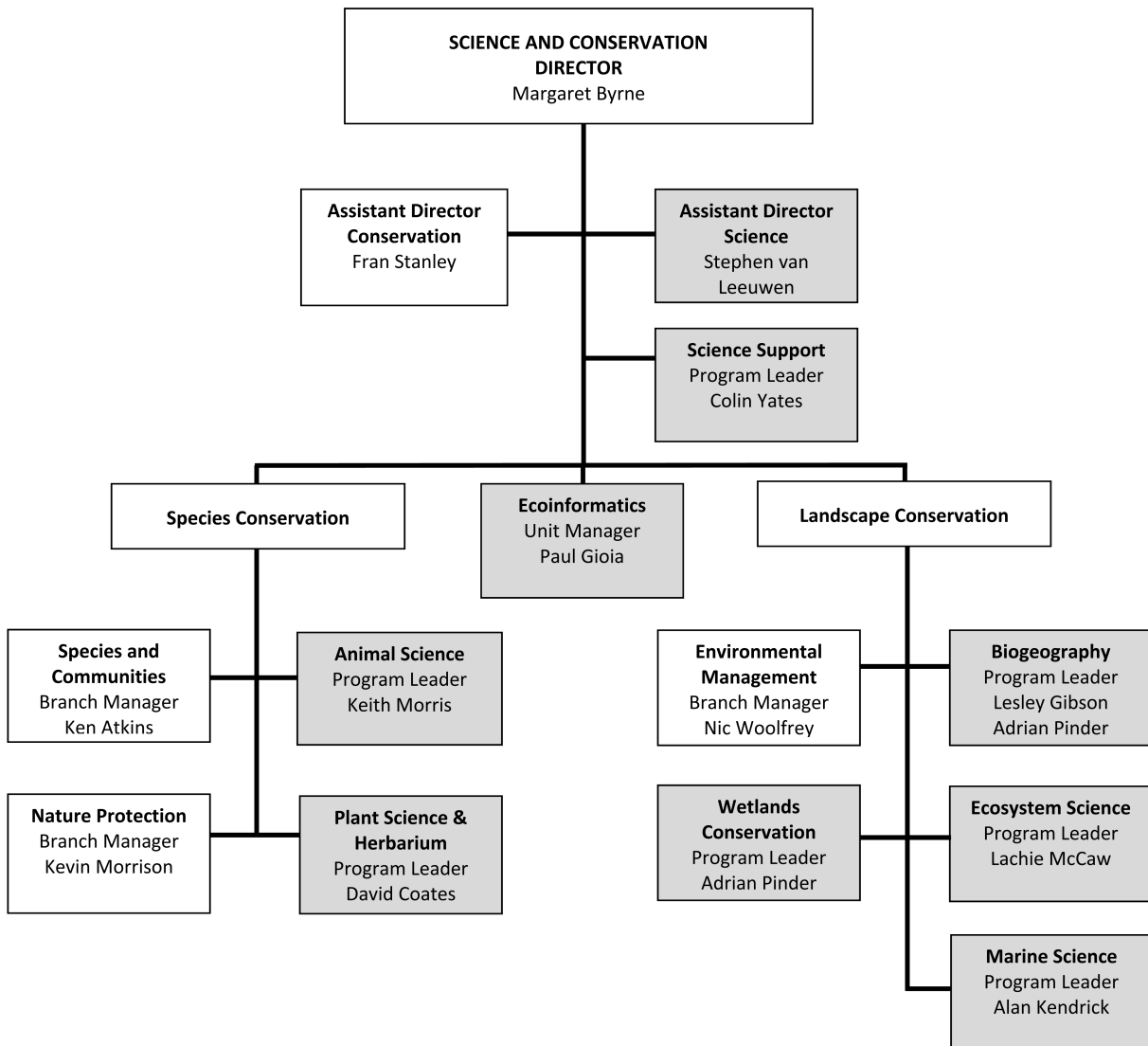
Service Delivery Structure	1
Report on research activities	2
Biogeography	2
South-Western Australia Transitional Transect (SWATT)	2
Biological survey and conservation planning for the Swan Coastal Plain bioregion and adjacent scarps (Dandaragan, Darling and Whicher)	3
Western Australian flora surveys	4
Western Australian terrestrial fauna surveys	5
Plant species richness and endemism within the south-western Australian Floristic Region	7
Development of ethically acceptable techniques for invertebrate wet-pit trapping	7
Kimberley islands biological survey	8
Pilbara region biological survey	9
Animal Science	11
Improved fauna recovery in the Pilbara – Assessing the uptake of feral cat baits by northern quolls, and their associated survivorship	11
Cat Eradication on Dirk Hartog Island	12
Monitoring of threatened birds on Dirk Hartog Island	13
Improving the use of remote cameras as a survey and monitoring tool	14
Decision support system for prioritising and implementing biosecurity on Western Australia’s islands	15
Conservation and management of the bilby (<i>Macrotis lagotis</i>) in the Pilbara	17
Genetic assessment for conservation of rare and threatened fauna	18
Genetic approaches for evaluating the contribution of the reserve system to fauna conservation	19
Barrow Island Threatened and Priority fauna species translocation program	20
Rangelands restoration: reintroduction of native mammals to Lorna Glen (Matuwa)	21
Feral cat control and numbat recovery in Dryandra woodland and other sites	23
Conservation of south coast threatened birds	24
Ecology and management of the northern quoll in the Pilbara	25
Conservation of the graceful sun-moth	26
Impact of cane toads on biodiversity in the Kimberley	27
Development of effective broad-scale aerial baiting strategies for the control of feral cats	28
Gilbert’s potoroo (<i>Potorous gilbertii</i>) recovery plan	30
Plant Science and Herbarium	32
Is restoration working? An ecological assessment	32
Interactive key and taxonomic studies of Myrtaceae tribe Chamelaucieae	33
Biosystematics of fungi for conservation and restoration of Western Australia’s biota	34
Climate change risks for biodiversity and ecosystem function in species-rich shrublands	35
Strategic taxonomic studies in families including Amaranthaceae and Fabaceae (<i>Ptilotus</i> , <i>Gomphrena</i> , <i>Swainsona</i>) and other plant groups	36
The Western Australian Plant Census and Australian Plant Census	37
The Western Australian Herbarium’s specimen database	38
Herbarium collections management	39
Biodiversity informatics at the Western Australian Herbarium	40
Taxonomy of undescribed taxa in the Ericaceae subfamily Styphelioideae, with an emphasis on those of conservation concern	41
Taxonomic studies on native and naturalised plants of Western Australia arising from biological survey	42
Resolving the systematics and taxonomy of <i>Tephrosia</i> in Western Australia	43

Taxonomy of selected families including legumes, grasses and lilies	44
Temperature thresholds for recruitment in south-west Western Australian flora	46
Systematics of the triggerplant genus <i>Stylidium</i>	47
Taxonomic review and floristic studies of the benthic marine algae of north-western Australian and floristic surveys of Western Australian marine benthic algae	47
The Western Australian marine benthic algae online and an interactive key to the genera of Australian marine benthic algae	49
Taxonomic resolution and description of new plant species, particularly Priority Flora from those areas subject to mining in Western Australia	50
Development of interactive identification platforms and content	51
Genetic and ecological viability of plant populations in remnant vegetation	51
Translocation of critically endangered plants	53
Mating system variation, genetic diversity and viability of small fragmented populations of threatened flora, and other key plants of conservation importance	54
The population ecology of critically endangered flora	55
Seed biology, seedbank dynamics and collection and storage of seed of rare and threatened Western Australian taxa	56
Genetics and biosystematics for the conservation, circumscription and management of the Western Australian flora	57
Ecosystem Science	59
Development of an environmental risk strategy for sustainable agricultural planning in the Kimberley	59
Understanding the changing fire environment of south-west Western Australia	60
Restoring natural riparian vegetation systems along the Warren and Donnelly Rivers	61
Responses of terrestrial vertebrates to timber harvesting in the jarrah forest	63
Fire behavior and fuel dynamics in coastal shrublands	64
Long term response of jarrah forest understorey and tree health to fire regimes	65
North Kimberley Landscape Conservation Initiative: monitoring and evaluation	66
Climate-resilient vegetation of multi-use landscapes: exploiting genetic variability in widespread species	67
Long-term stand dynamics of regrowth forest in relation to site productivity and climate	68
Management of invertebrate pests in forests of south-west Western Australia	69
Protecting the safe havens: will granite outcrop environments serve as refuges for flora threatened by climate change?	71
Fire regimes and impacts in transitional woodlands and shrublands	72
Identification of seed collection zones for rehabilitation	73
FORESTCHECK: Integrated site-based monitoring of the effects of timber harvesting and silviculture in the jarrah forest	74
Burning for biodiversity: Walpole fine-grain mosaic burning trial	75
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	76
Landscape and fire management interactions and their effects on distribution of invertebrate biodiversity	78
Hydrological response to timber harvesting and associated silviculture in the intermediate rainfall zone of the northern jarrah forest	79
Genetic analysis for the development of vegetation services and sustainable environmental management	80
Wetlands Conservation	83
Responses of aquatic invertebrate communities to changing hydrology and water quality in streams and significant wetlands of the south-west forests of Western Australia	83
South West Wetlands Monitoring Program (SWWMP)	84
Advancing the hydrological understanding of key Wheatbelt catchments and wetlands to inform adaptive management	86
Taxonomy, zoogeography and conservation status of aquatic invertebrates	87

Understanding peat wetland resilience: evaluating the impact of climate and landuse change on the hydrodynamics and hydrogeochemistry of peat wetlands in the Warren (Muir-Byenup) District	88
Western Australian wetland fauna surveys	89
Marine Science	91
Long-term monitoring in the proposed Dampier Archipelago marine reserves	91
Habitat use, distribution and abundance of coastal dolphin species in the Pilbara	92
Distribution and abundance estimate of Australian snubfin dolphins (<i>Orcaella heinsohni</i>) at a key site in the Kimberley region, Western Australia	93
Access and human use at Penguin Island and related implications for management of Marine Park assets and visitor risk	94
Improving the understanding of West Pilbara marine habitats and associated taxa: their connectivity and recovery potential following natural and human induced disturbance	96
The influence of macroalgal fields on coral reef fish	97
Understanding movements and identifying important habitats of sea turtles in Western Australia	98
The Western Australian Marine Monitoring Program (WAMMP)	99
Review, assess and summarise historical data relevant to the management of the proposed Dampier Archipelago Marine Park and Regnard Marine Management Area	101
North West Shelf Flatback Turtle Conservation Program strategic plan	101
WAMSI 2: Kimberley Marine Research Program	102
Effects of the Gorgon Project dredging program on the marine biodiversity of the Montebello/Barrow Islands marine protected areas	104
Spatial and temporal patterns in benthic invertebrate communities of the Walpole and Nornalup Inlets Marine Park	105
Interactive effects of fishing and climate change on coral reef fish populations	106
Spatial and temporal patterns in the structure of intertidal reef communities in the marine parks of south-western Australia	107
Ecoinformatics	109
Provision of authoritative names of Western Australian taxa	109
Online GIS biodiversity mapping (<i>NatureMap</i>)	110
External Partnerships	112
Current Collaboration with Academia (Student Projects)	119
Student Projects	123
Population estimate and habitat of the Christmas Island Hawk-owl (<i>Ninox natalis</i>)	123
Ecology of the feral cat (<i>Felis catus</i>) in coastal heaths of the south coast of Western Australia	123
Parasites and diet of feral cats and rodents on mainland Western Australia and offshore Islands (Christmas Island and Dirk Hartog Island)	124
The ecology and interactions of dingoes and feral cats in the arid Rangelands of Western Australia	125
Vegetation responses to Noongar land management practices in old and young landscapes	125
Assessment of hybrid status and conservation significance of intermediate populations within the <i>Stylidium caricifolium</i> complex (Stylidiaceae) in southwest Western Australia	126
Improving our understanding of high latitude coral communities in temperate Western Australia: biogeography, latitudinal growth patterns, connectivity-fecundity-recruitment and competitive tolerance to seaweeds	127
The impacts of suspended sediment on fish assemblage structure in northwest Australia	128
Assessing the drivers of fish distribution patterns within the Ningaloo Marine Park, Western Australia	128
A novel stereo-video method to investigate fish-habitat relationships	129
The role of <i>Kyphosus</i> spp. in reef ecosystems	129
Recovery of karri forest after an extreme wildfire in Northcliffe.	130
Ecological genetic assessment of <i>Hakea laurina</i> in restoration sites compared with remnant bush	130
Ecology and taxonomic differentiation in the Australian water rat and implications for its conservation status in Western Australia	131
Genetic consequences of mammal translocations in Western Australia using case studies of dibblers, bodgies and black-flanked rock wallabies	132

Nutrient movement and its impact on aquatic invertebrates as a food source for waterbirds between different wetland suites within the Lake Warden wetland system	132
Phylogeny, systematics and evolution of the Australian arid-zone <i>Ptilotus</i>	133
Diversity in the <i>Triodia basedowii</i> E.Pritz. species complex and its implications for the evolution of the Australian arid zone biota	133
Are <i>Banksia</i> species changing in response to a drying climate? An investigation of potential range contraction and leaf indices of stress	134
The role of <i>Toxoplasma gondii</i> in declining populations of the woylie (<i>Bettongia penicillata ogilbyi</i>) . . .	135
Investigating the impact of polyparasitism in translocated woylies (<i>Bettongia penicillata</i>), and the effect of anti-parasite treatment on host fitness and survivability.	135
Population estimates of the threatened western ringtail possum (<i>Pseudocheirus occidentalis</i>) and common brushtail possum (<i>Trichosurus vulpecula</i>) in conservation and harvested forests of southwestern Australia.	136
Wildlife ecology in the southern jarrah forest	136
Stress and disease in critically endangered woylies (<i>Bettongia penicillata</i>)	137
A comparative health and disease investigation in the woylie: captive vs free-range enclosure vs wild	138
Pathogen transmission in the critically endangered woylie: a community, population, and individual approach	138
Validating management options for maximising genetic success in translocation programs for the Woylie (<i>Bettongia penicillata ogilbyi</i>)	139
Genetic diversity of <i>Blastocystis</i> isolates found in West Australian native fauna	140
Ecological study of the quokka (<i>Setonix brachyurus</i>) in the southern forests of south-west Western Australia	140
Understanding the early offshore movement of flatback turtle hatchlings and the effects of anthropogenic light	141
The health status of marine turtles in northern and western Australia	142
Evidence based management of foxes adjacent to turtle beaches in Western Australia	142
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	143
The effect of patch habitat networks in shaping the distribution, abundance and diversity of coastal fishes	143
Variation in the intensity of periodic harvests in Fijian tabu areas and the effect on reef fish assemblages	144
The significance of macroalgae to the diets of juvenile fishes and the ecosystem function of the Ningaloo Reef lagoon	144
Can diver operated stereo-video surveys of fish be used to collect meaningful data on tropical coral reef communities for long term monitoring?	145
Publications and Reports	146
Summary of Research Projects	157

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.

Report on research activities

Biogeography

Program Leader: Lesley Gibson and Adrian Pinder

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 other herbaria and museums throughout Australia, and with universities, cooperative research centres, CSIRO and other research institutions. Partnerships also exist with traditional owners, resource companies and the environmental consulting industry.

South-Western Australia Transitional Transect (SWATT)

SP 2013-003

Team

S van Leeuwen, N Gibson, R Meissner, M Langley

Context

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

- Further data analysis has been undertaken to better understand patterns in sandplain beta diversity and complementarity with patterns in the Yilgarn Banded Ironstone Formations.

- Plant specimens have been selected and prepared for lodgement in herbarium.
- Identification of isotopic signature in plants to delimit climate niche and species turnover along SWATT has commenced.

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

- Publish paper on patterns of sandplain beta diversity and complementarity in patterns observed with respect to those previously identified for the Banded Iron Formation ranges of the Yilgarn.
- Locate additional long-term sampling plots on the SWATT in collaboration with the Terrestrial Ecosystems Research Networks' AusPlots facility.

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

SP 2012-032

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 published in press.
- Paper on Lambert Lane Nature Reserve published.
- 2015 surveys of South Bunbury, Ippollo Road and Harrisdale Swamp undertaken.
- Discussion paper on vegetation complex mapping prepared for funding proposal.
- Review paper on floristics of Banksia woodlands in press.

Management implications

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

Future directions

- Update information on and complete monitoring sites for the south Bunbury greenways corridor using volunteers in association with South West Catchment Council (SWCC), City of Bunbury and the Department of Parks and Wildlife's South West Region in spring 2016.

Western Australian flora surveys

SP 2012-005

Team

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

Context

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

Current projects include:

- AusPlots Rangeland survey sites as a baseline for long-term surveillance monitoring in collaboration with the Terrestrial Ecosystems Research Network (TERN). This AusPlots Western Australian campaign will focus on rangeland bioregions including the South West Australia Transitional Transect (SWATT) in the Great Western Woodlands.
- Flora survey of the Katjarra (Carnarvon Range) Indigenous Protected Area in collaboration with the Biriliburu Native Title Claimants to aid future management.
- Floristic survey and mapping of the halophyte-dominated communities of the Fortescue Marsh.
- Capture of vegetation mapping data for the Great Western Woodlands, Indian Ocean Drive and central Pilbara to inform natural resource management and land use planning.
- Black spot flora survey of the Peterswald 1:100,000 map sheet.
- Study of the impacts of weeds and grazing following prescribed fire in a *Banksia* woodland.
- Resurvey of threatened claypan communities on the Swan Coastal Plain documenting change over 20 years.
- Floristic survey of the mound springs and surrounding vegetation communities of Mandora Marsh / Waylarta in collaboration with the West Kimberley District.
- Floristic survey of the coastal wetlands of the Jurien area.

Aims

- To undertake targeted surveys for particular purposes. These targeted short duration surveys are primarily aimed at providing specific management advice, monitor long term change in vegetation at specific sites or in specific communities, or to fill specific data gaps.

Progress

- Flora survey report of Peterswald has been finalised.
- Field component of the flora survey of Colville has been completed, plant identifications are continuing.
- Paper on impacts of fire in urban remnant has been published.
- Claypan dataset has been compiled, analysis is continuing.
- Floristic communities have been described for the Fortescue Marsh, and mapping of halophyte-dominated communities is currently underway.
- Flora survey of Mandora Marsh / Walyarta has been finalised and a draft report prepared for the West Kimberley Region.
- Jurien coastal wetlands survey completed, preparation of scientific paper underway.
- Vegetation map reconciliation continued with the digital capture of over 360,000 ha of mapping in the central Hamersley Range between Munjina and Weelumurra.
- A Pilbara AusPlots campaign established 19 plots in the Fortescue catchment between Millstream Chichester and Karijini National Parks.

Management implications

- The survey of the Colville area will increase the flora known from this area and assist in land use planning and impact assessments for future resource development.
- Fire study will inform weed management following fire in long unburnt urban remnants.
- Analysis of the claypan data will provide information on the temporal variation in these nationally threatened communities, and develop methods to assess ecosystem health.
- Survey of Mandora Marsh / Walyarta and the Fortescue Marsh will provide information for draft management plans for existing and proposed reserves in the southern Kimberley and Pilbara.
- The Jurien coastal survey will provide information on wetland flora values to assist in land use planning and impact assessments for mining and water resource developments.
- The digital capture and reconciliation of vegetation maps will inform environmental impact assessment processes associated with native Vegetation Clearing permits and major resource development proposals. This information will also enable fire management planning, particularly the development of burning prescriptions for Karijini National Park.

Future directions

- Further surveys will be undertaken as required and when resources become available. 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. Another Pilbara AusPlots campaign is planned for 2016 and resources may also be forthcoming to expand this survey effort into the Kimberley and onto the Swan Coastal Plain.

Western Australian terrestrial fauna surveys

SP 2011-021

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 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 September 2015, a survey in a remote part of the northern Nullarbor was undertaken (Colville 1:100,000 map sheet) in collaboration with the Goldfields Region and a report on the results of the vertebrate survey was produced.
- In September 2015 a survey of the area around Kiwirrkurra in the eastern Gibson Desert was undertaken, as a collaboration between the Traditional Owners, the Western Australian Museum and the Australian Government's BushBlitz Program. The work focused in an area with little terrestrial vertebrate information, and along with extensive DNA collections, populations of several rare species were identified. A report on this work has been completed and all data have been submitted to the BushBlitz Team. Genetic samples and voucher specimens have been lodged with the Western Australian Museum.
- Survey and monitoring guidelines for the sandhill dunnart (*Sminthopsis psammophila*), and a baseline survey design in the Great Victoria Desert, were completed.

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 development proposals. Individual survey projects assist regional conservation and land managers to understand local biodiversity patterning and its underlying drivers, and permit the use of this information to assess environmental impacts, prioritise conservation actions, set biodiversity management targets and establish baselines for monitoring and detecting change. The combination of surveys enables improved understanding of species distributions and habitat requirements at a State level, thus contributing to bioregional analyses, assessment of the design of the conservation estate, reviews of species conservation status and analyses of the relationships between species and broad-scale gradients and threats such as climate change.

Future directions

- Colville map sheet data uploaded to NatureMap.
- Peterswald map sheet vertebrate report completed.
- The development of collaborative arrangements to facilitate future surveys is ongoing.

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

SP 2011-010

Team

P Gioia

Context

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

Aims

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

Progress

- Draft manuscript has been submitted for internal review.

Management implications

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

Future directions

- Submit manuscript for publication

Development of ethically acceptable techniques for invertebrate wet-pit trapping

SP 2010-005

Team

M Cowan, N Guthrie

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.
- Solution requires minimal personal protective equipment for safe use and poses no environmental risk or hazard.
- Solution needs to be stable for several weeks or more under variable climatic conditions.

Progress

- DNA extraction and PCR amplification trials have been undertaken from a number of preserved specimens collected in the field with positive results.
- Reports have been provided to the Parks and Wildlife Animal Ethics Committee.
- Advice has been provided to the Animal Ethics Committee in relation to applications to use invertebrate wet pit traps.

Management implications

- An alternative to the ethylene glycol and formalin solutions used in invertebrate wet pitfall trapping that reduce or address existing ethical issues around vertebrate by-catch may allow for the continuation of this type of invertebrate sampling method. This is not only important for the Department of Parks and Wildlife's existing survey and monitoring programs but for other government agencies, tertiary institutions and environmental consultants that utilise this methodology for sampling ground invertebrates. Of particular relevance will be the increased value of preserved material for morphological and molecular examination, an area that is currently severely compromised by material collected using the conventional ethylene glycol and formalin solutions.

Future directions

- Continue provision of advice to the Department's Animal Ethics Committee on the use of invertebrate wet pits.
- Project will be completed once final integration report is compiled.

Kimberley islands biological survey

SP 2007-001

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 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 was officially published.
- Survey data has been submitted to NatureMap.

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

- Finalise data ingestion to NatureMap and lodgement of plant specimens into the Western Australian Herbarium.

Pilbara region biological survey

SP 2004-002

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 paper on the importance of habitat, connectivity and dispersal ability for Pilbara riverine aquatic invertebrate beta diversity was published.
- Aquatic invertebrate data is being used to analyse drivers of aquatic invertebrate beta diversity across the Australian arid zone.
- A further 3000 plant voucher collections have been lodged with the Western Australian Herbarium.
- Part 2 (hardcover volume) of Supplement 78, Records of the Western Australian Museum, collating reptile and frog, historical bird, stygofauna, aquatic flora, riparian flora and conservation gap analyses papers was published.
- Parts 1 and 2 of Supplement 78, Records of the Western Australian Museum (A biodiversity survey of the Pilbara Region of Western Australia), were officially launched.
- Four reptile taxonomic papers, including two revisions, were published.

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

- Complete and analyse the terrestrial flora matrix then draft and submit the flora paper for publication.
- Continue to undertake communication activities on survey findings and outputs.
- Upload all datasets to NatureMap.

Animal Science

Program Leader: Keith Morris

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

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

SP 2015-016

Team

K Morris, M Cowan, J Angus, S Garretson, 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*^Á® 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.

Aims

- To assess the field uptake of *Eradicat*^Á® 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

- Radio collars were attached to 21 northern quolls at Yarraloola to enable tracking and determination of fate through a trial *Eradicat*^Á® baiting. As a control, 20 individuals were also collared at Red Hill.
- *Eradicat*^Á® feral cat baiting of a 20,000 ha area at Yarraloola was undertaken in July 2015.
- Tracking of all animals was carried out prior to baiting through to the last collar removal in October 2015. During this time there were five predation events at Yarraloola and seven at Red Hill with the majority of these attributable to feral cats.
- Of the radiocollared quolls, there were no deaths as a result of *Eradicat*^Á® bait ingestion.
- There was no evidence of any reproductive impacts from *Eradicat*^Á® baits on the monitored female northern quolls (number of pouch young were higher at Yarraloola than at Red Hill).
- Details on movement patterns of the radio collared animals at both Yarraloola and Red Hill were collated showing significant variation between the sexes.
- 12 trapping sites were established at both Yarraloola and Red Hill to provide baseline monitoring data. Captures from these sites were assessed to determine if this number of sites would provide sufficient

power to detect population change. Subsequent to review by the biometrician the number of monitoring sites will be increased to 18.

- Monthly progress reports were submitted to Rio Tinto throughout the field program.
- Final reports on the bait uptake and the monitoring trials were submitted to Rio Tinto at the end of 2015, and used in an application to use *Eradicat*^Á® baits over >100,000 ha in 2016.

Management implications

- As no detrimental impacts to northern quolls were observed from this trial, an operational cat baiting campaign over a much larger area of Yarraloola (>100,000ha) will be undertaken in July 2016, subject to approval by the Australian Pesticides and Veterinary Medicines Authority (APVMA) .
- The lack of impact on northern quoll has broader implications for feral cat management in areas where northern quolls are known to occur.
- Development of sound trapping methodology for monitoring northern quoll numbers in areas of relatively low abundance will improve survey and monitoring programs.

Future directions

- Subject to satisfactory progress in 2016, implement large scale *Eradicat*^Á® feral cat baiting trials over Yarraloola on an annual basis until at least 2019.
- Use remote camera traps in a before-after-control-impact design to monitor the effect of *Eradicat*^Á® baiting on feral cats at Yarraloola.
- Continue monitoring northern quolls using established trapping sites at both Yarraloola and Red Hill to detect changes in population size as a response to on-ground management actions.
- Investigate the use of genetic tools to supplement trap based monitoring data.
- Pursue registration of *Eradicat*^Á® feral cat baits for operational use in areas where northern quolls are present.

Cat Eradication on Dirk Hartog Island

SP 2014-003

Team

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

Context

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

Aims

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

- Monitoring track access and camera traps for cats in both the southern and northern sections of Dirk Hartog Island continued.
- Cat activity is absent south of the barrier fence.
- Baiting of the northern section was undertaken in May 2015 and subsequent trapping has removed the majority of cats that remained post-baiting.

Management implications

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

Future directions

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

Monitoring of threatened birds on Dirk Hartog Island

SP 2013-021

Team

A 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 DHI.
- 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

- Distance sampling techniques have been utilised in spring 2015, and preliminary population estimates calculated. It is estimated that there are 36,650 southern emu-wrens, 24,700 white-winged fairy-wrens and 20,750 rufous fieldwrens on DHI.

- A phylogenetic analysis for the DHI rufous fieldwren has been further developed in collaboration with staff at the Western Australian Museum. This suggests that there is little genetic differentiation of the DHI form from other western rufous fieldwrens.

Management implications

- This baseline monitoring will assist in interpreting the response of the DHI extant fauna to removal of goats and 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.
- Monitoring and analysis has shown little support for the rufous fieldwren on DHI being listed as a threatened species.

Future directions

- Carry out further distance sampling to provide robust 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.

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

SP 2013-005

Team

N Thomas, M Cowan, B MacMahon, S Garretson

Context

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

Aims

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

Progress

- The project has been incorporated, as a major field component, into the South West Fauna Recovery Project (Dryandra) with much of the day to day running of the field program being undertaken by the Great Southern District.
- A Science and Conservation Information Sheet on assessing camera traps to census mammals has been prepared.
- There have been ongoing developments with the open source Access database, CPW Photo Warehouse, as modifications are requested from departmental users to meet their specific requirement for a database to manage camera trap images.
- Reported to South West Fauna Recovery Project team the detection rates and spatial patterns for all critical weight range mammals and larger species within the primary Dryandra block for 2014. Data from 2015 to present is currently being assessed.
- Delivered presentation on using camera traps to the Kwongan Foundation's annual conference and to The University of Western Australia's Environmental Studies Group.

Management implications

- Analysis has shown that camera traps are an effective tool for detecting a suite of species currently not adequately monitored by the Western Shield program. However, there is growing evidence that they may have biases in detecting some species and this needs to be taken into consideration, particularly where lures or baits are used as there is a considerable risk of introducing bias in detections.
- Managers need to give special consideration to the specific species being targeted, questions being addressed, type of camera trap, survey design and set-up before undertaking any camera trap survey.
- Reconyx camera traps (models HC600 and PC900) continue to be the most effective commercially available camera traps for departmental requirements and remain recommended for use.

Future directions

- Ongoing assessment of on track/off track use of camera traps to quantitatively monitor foxes and feral cats in Dryandra.
- Investigate potential biases in detections when using camera traps to monitor fauna and pest species, such as trap avoidance/behavioural changes, and how to mitigate these biases.
- Integrate Dryandra camera trap work as a monitoring technique for cat bait effectiveness trials.
- Continue work on reviewing and/or modifying open source Access Camera trap databases 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.

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

SP 2013-001

Team

C Lohr, K Morris, L Gibson

Context

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

has over 3700 islands, many of which are essential for the survival of threatened species and provide critical breeding sites for seabirds and sea turtles. Many islands are also popular sites for recreation, and contain culturally significant sites. Invasive species are the single biggest cause of loss of native species from islands. The increased use of islands by the public for recreation, and oil, gas and mining industries, means an increased likelihood that invasive species will colonise pristine islands.

This project will develop:

1. decision support software for day-to-day use in making accountable and cost-effective decisions on the management of islands to promote the persistence of native species; and
2. an island biosecurity model for prioritising biosecurity actions.

The project will initially focus on the 600+ islands along the Pilbara coast.

Aims

- Develop a single comprehensive database on Pilbara island characteristics, fauna and flora values, and threats.
- Develop an operational decision support software for day-to-day use in making accountable and cost-effective decisions about where to spend limited funding on management of islands to promote the persistence of native species.
- Develop an island biosecurity model for use in prioritising surveillance tasks for non-indigenous species on Pilbara islands.

Progress

- Version 2 of decision support software presented to Parks and Wildlife staff and external researchers at dedicated symposium.
- Graphical user interface refined, and user manual drafted.
- Development of island biosecurity model complete, manual being drafted.
- Pilbara island database: 99% available historical data entered; new data from Pilbara Regional staff regularly entered.
- Species attributes database is under development.
- Pilbara islands habitat map is being refined and validated.
- Presentations at Island Arks Symposium III, Australasian Wildlife Management Society, 27th International Congress for Conservation Biology, 7th Annual Conference of the Australasian Bayesian Network Society, and the 30th Association for the Advancement of Artificial Intelligence Conference.
- Journal articles, four published, four in review.

Management implications

- The decision support software will result in more cost effective 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.
- A species attributes database will facilitate species management across Western Australia and the identification of priorities with regard to quarantine, surveillance, and biological survey on Pilbara islands.

Future directions

- Finalise decision support tool and biosecurity model user manuals and develop training courses.
- Use habitat maps to identify gaps in island biodiversity knowledge and survey history, and model native species distributions and assemblages.
- Use decision support software to draft an initial set of management priorities for Pilbara Islands and identify island surveillance priorities for priority non-indigenous species.

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

SP 2012-035

Team

M Dziminski, K Morris, F Carpenter

Context

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

Aims

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

Progress

- Current and historic records of bilbies in the Pilbara have continued to be accessed from many sources. To date 1059 records of bilbies have been collated and uploaded into the Pilbara Threatened Fauna Database, which is linked to NatureMap.
- Using the current technique of 2 ha plots, 1209 plots in likely bilby habitat have been surveyed for the presence of bilbies across the Pilbara. Confirmed evidence of bilby presence was recorded at 254 of these (21%) plots. Sufficient presence data has now been gathered to enable accurate modelling the distribution of bilbies in the Pilbara.
- Data from Remotely Piloted Aircraft trials showed that it is possible to use this technology to detect bilby signs, such as burrows and diggings.
- A study of the effect of time on DNA degradation found that DNA exists in bilby faecal pellets for a long period of time and can be amplified with a high success rate with low errors. A population monitoring technique to measure abundance has been developed using DNA extracted from faecal pellets quantitatively collected in the field.
- A study examining the use of bilby burrows by other species found that both occupied and disused burrows are important for a range of other mammals, birds and reptiles.
- Public awareness campaign for bilbies in the Pilbara continues with information sessions and public presentations being delivered in the Pilbara, Kimberley and Perth together with radio and newspaper articles.

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.
- Monitoring has shown that populations in the Pilbara are isolated and consist of a small number of individuals which implies that they are extremely vulnerable to threats.

- Bilby burrows are important habitat for a suite of species and ensuring the persistence of bilbies where they still occur and reintroducing bilbies back to areas they once occupied will have positive effects on biodiversity.

Future directions

- Optimise remotely piloted aircraft technology to survey for bilbies.
- Include more populations to the long-term monitoring program, developing more collaborations with stakeholders to monitor bilbies on their tenure.
- Determine optimum storage technique for field collected scats for DNA extraction.

Genetic assessment for conservation of rare and threatened fauna

SP 2012-034

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 (*Isodon* sp.), particularly *I. auratus* and *I. obesulus* and their subspecies, to determine appropriate conservation rankings.
- In collaboration with Brian Chambers (The University of Western Australia) 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 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 and a preliminary report written and submitted. Further analyses using a more powerful genomics approach are required to fully resolve species boundaries between *I. obesulus* and *I. auratus*. However, a population genetic analysis is currently underway to designate 'management units' in Western Australian bandicoots. Population viability analyses of urban quenda populations impacted by road construction have been completed exploring the long-term trajectory of populations with and without fauna underpasses, and with an additional range of threats (fire, urban expansion, inbreeding). A manuscript has been submitted and a further manuscript documenting quenda mating patterns in remnant populations is being prepared.
- Preliminary data analysis of genetic diversity and structure of wheatbelt and mid-north rock wallaby populations has been completed.

- DNA barcoding was used to identify a stranded dolphin carcass as a Australian snubfin dolphin hybrid, most likely with a Indo-Pacific humpback dolphin.

Management implications

- An Australia-wide phylogenetic assessment of *I. obesulus* and related species/subspecies has enabled a more informed evaluation of taxonomic boundaries, showing that *I. o. obesulus* is restricted to eastern and southeastern Australia and identifying a range extension of *I. o. fusciventer* (Western Australia) into South Australia. The threat status is currently being evaluated at the Commonwealth level for the eastern and Tasmanian sub-species of *I. obesulus*.
- Genetic and population viability analysis showed that quenda populations in small, isolated patches of remnant vegetation in the urban matrix are vulnerable to genetic erosion, inbreeding and population decline, particularly when connectivity within (fauna underpasses) or between (increased urbanisation) habitat patches is inhibited. The impact of fauna underpasses on population persistence is somewhat context-specific, but extinction risks are predicted to increase in populations without fauna underpasses.
- Genetic information on rock wallaby populations will enable evaluation of the current status of nearly all extant populations, including the assessment of the effectiveness of past management interventions, and will contribute to planning of future conservation actions, including translocations.
- The presence of rare dolphin hybrids in Australian waters contributes to our knowledge of hybridization in the marine environment.

Future directions

- Continue phylogenomic analysis of the genus *Isoodon* to formally resolve the species boundaries across the group.
- Complete manuscripts of urban quenda populations (population viability analysis and mating systems, including parentage assignment of individuals using fauna underpasses).
- Comparison of historic and contemporary population genetics of wheatbelt rock wallaby populations to monitor genetic change and investigate impact of past management actions. Develop population viability analyses to predict future trajectory of threatened populations.

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

SP 2012-033

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

- DNA extraction and genotyping of quenda tissue samples from the Swan Coastal Plain and Perth hills has been completed. Landscape (species distribution model) and genetic analyses are currently underway.
- DNA extractions, microsatellite genotyping and mitochondrial sequencing has been completed for three target small mammal species in the Pilbara. Collation of GIS datasets and genetic analyses are currently underway.

Management implications

- This project and its constituent investigations will assess the adequacy of the current reserve system in conserving species genetic diversity and genetic processes such as gene flow. More broadly, the project 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. Assess genetic diversity patterns of quenda populations in continuous versus fragmented habitat.
- Analyse patterns of historical and contemporary population structure and genetic diversity of Pilbara small mammal species 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.

Barrow Island Threatened and Priority fauna species translocation program

SP 2012-025

Team

N Thomas, K Morris, 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 Western Australian Government approved the development of the Gorgon gas field off the north west of Barrow Island, and associated LNG plant on Barrow Island, subject to several environmental offset conditions. One of these 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

- Golden bandicoots from the captive population within the enclosure at Matuwa (Lorna Glen) were translocated outside the enclosure in September 2015 and appear to have established following an intensive feral cat and dog control program.
- Golden bandicoots and boodies translocated from Barrow Island to the fenced enclosure at Matuwa in 2010 were monitored and continue to maintain good body/reproductive condition.
- Golden bandicoots introduced to Doole Island from Barrow Island in 2011 were monitored and found to now occupy most of the island.
- A camera trap array was used to estimate the occupancy of spectacled hare-wallabies on Hermite island and showed that the hare-wallabies have continued to expand and now occupy most of the island.
- Black-and-white fairy-wrens and spinifexbirds translocated from Barrow Island to Hermite Island in 2010/11 were monitored. Both species have shown strong increases in population size and spinifexbirds have self-dispersed to six additional islands.
- An annual report on progress was provided to Chevron.

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. The outcomes will also contribute to an improvement in the conservation status of several threatened fauna taxa and provide the basis for ongoing monitoring of fauna on the Montebello Islands by the Pilbara Region.

Future directions

- Continue to implement the Barrow Island fauna translocation strategy.
- Research into the effectiveness of feral cat baiting at Cape Range to be undertaken in 2016/17 so that an integrated fox/cat baiting regime can be developed to support the locality becoming a possible reintroduction site.
- Ongoing monitoring of the translocated mammals and birds at all the release sites.
- Continue to plan for an expanded fenced enclosure at Matuwa in the context of a joint management agreement for the Indigenous Protected Area with Martu traditional owners.

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

SP 2012-024

Team

C Sims, M Blythman, K Morris, N Burrows

Context

Operation Rangelands Restoration commenced in 2000 with the acquisition of Lorna Glen and Earacheedy 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 Earacheedy (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

- Development of positive relationships and joint management activities with the Martu traditional owners of Matuwa Indigenous Protected Area (ex Lorna Glen).
- Annual monitoring of mulgara (*Dasyercus blythi*) populations inside and outside the enclosure indicate that this species continues to be abundant and has responded positively to feral cat control.
- Track and scat/DNA surveys have established widespread presence of bilbies across the Bullimore sand plain land system.
- Persistence of possums in core habitat has been determined and collection of DNA has been made for comparisons of genetic diversity with other Western Australian populations.
- Ongoing monitoring of boodies and bandicoots inside the enclosure indicates good population numbers and reproductive rates persist.
- Increased presence and sightings of mala inside enclosure.
- Successful *Eradicat*[®] baiting in 2015, resulted in a 60-70% reduction in cat numbers across the property, demonstrated by both Track Count Indices and Infra-Red camera grids.
- Successful reintroduction of golden bandicoots into two sites outside the enclosure. Success was measured through persistence of founders and presence of new recruits (F1), and increased dispersal of bandicoot tracks across the Bullimore sand plain habitat.

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.

- Monitoring has demonstrated that additional cat control techniques to landscape scale baiting are required to successfully re-establish fauna in the rangelands.

Future directions

- Development of future engagement and cooperation with traditional owners in management and monitoring activities.
- Ongoing monitoring of bilbies and possums outside the enclosure, and of bandicoots, boodies, mala and Shark Bay mice inside the enclosure.
- Develop plan for reintroductions of red tailed phascogales in 2017.
- Investigate the genetic health of possum population and assess need for future genetic supplementation.
- Assess the need for restocking the bandicoot population outside the fenced enclosure.

Feral cat control and numbat recovery in Dryandra woodland and other sites

SP 2012-023

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

- To determine the uptake of rhodamine-labelled non-toxic *Eradicat*[®] baits by chuditch, red-tailed phascogales and mardos in Dryandra.
- 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.
- To determine the survival or mortality of feral cats through a baiting campaign using toxic *Eradicat*[®] baits in Dryandra.

Progress

- Four of the eight chuditch radio-collared at Dryandra in 2015 were recaptured and their collars removed. The other four were not found or trapped before their collars failed.
- Camera traps were set at Tutanning Nature Reserve in March 2016 to monitor cats before and after an *Eradicat*[®] baiting event. Of 37 cameras deployed around tracks in the reserve, 16 were stolen. As a result the camera monitoring was suspended. *Eradicat*[®] baiting was carried out as programmed in April 2016.

Management implications

- *Eradicat*^{Å®} can be used with minimal non-target impacts in the Dryandra Woodland. This is significant for the implementation of integrated fox and feral cat control programs at Dryandra and elsewhere in the south-west of Western Australia.

Future directions

- Repeat an *Eradicat*^{Å®} trial with GPS collared cats in Dryandra Woodland in 2016-17 to determine the effectiveness of this control method.
- Assess the effectiveness of setting leg-hold traps in raised sites (buckets of sand) for cats to reduce non-target capture.
- Monitor cat density before and after baiting using camera traps.
- Carry out an additional trial to determine the risk to red-tailed phascogale from *Eradicat*^{Å®} baiting by monitoring 8-10 radio-collared phascogales through a baiting event at Dryandra and Tutanning.

Conservation of south coast threatened birds

SP 2012-022

Team

A Burbidge

Context

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

Aims

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

Progress

- Continued integrated predator management on the south coast in an adaptive management framework, including monitoring western ground parrots before and after extensive fires in Cape Arid National Park and Nuytsland Nature Reserve.
- Ground parrot monitoring protocols are being refined through use of audio recordings and analysis of trends in current data set.
- Finalised genetic analysis of western whipbird phylogeny; outcomes being incorporated into formal conservation status listing; manuscript submitted for publication.

- In collaboration with South Coast Region, assisted in capture of two more western ground parrots and transfer to captive colony at Perth Zoo.
- Assisted in design, conduct and reporting on a national emergency workshop to create a better future for the western ground parrot.

Management implications

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

Future directions

- Finalise writing up of data on response to fire by bristlebirds and write up data on morphometrics of the western ground parrot.
- Publish western whipbird taxonomy paper.
- Implement further field-scale feral cat control (with monitoring) in key western ground parrot habitat within the South Coast Region.
- Continue to develop monitoring analyses and techniques, and write up recent survey data.
- Assist in finalising reporting on western ground parrot workshop, dissemination of report, and initiation of action on recommendations.

Ecology and management of the northern quoll in the Pilbara

SP 2011-005

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

- The third season of regional northern quoll monitoring at ten sites commenced in May 2016.
- Predictive species distribution modelling was undertaken in collaboration with Edith Cowan University. Distribution maps have been produced, and expanded to include scenarios of climate change and cane toad invasion.
- Northern quoll distribution model paper has been produced and submitted for publication.
- Research priorities for the Pilbara northern quoll (as determined by 2013 workshop) were published in *Australian Mammalogy*.
- A third northern quoll workshop was hosted by Parks and Wildlife in May 2016 with support from Roy Hill.
- Quoll distributional data is continually added to the Pilbara Threatened Species portal in NatureMap.
- Dietary analysis was undertaken on 500 northern quoll scats from throughout the Pilbara.
- Manuscript for dietary analysis produced, and submitted for publication.
- Northern quoll spatial use and home range estimates were generated from an Honours project in association with Edith Cowan University.
- Novel GPS collars for northern quolls were tested in a field setting, and provided information on spatial use and interactions with infrastructure.

Management implications

- Enhanced distributional data that is publicly available in an online repository will enhance decision-making relating to northern quolls in the Pilbara. Future monitoring of northern quolls can be aligned with the methods of the regional program, to enable regional comparisons of population trends and change.
- Sophisticated northern quoll population distribution maps can be used to predict the likelihood of occurrence, and inform management decisions. Areas without data collection have been identified as priorities for ground-truthing, and key populations likely to be impacted by future threatening processes have been determined.
- Results from GPS tracking of northern quoll suggests that impacts can be limited if known quoll habitat is not fragmented or destroyed by infrastructure developments.
- Modelling the changes in mortality of different cohorts of northern quolls has enabled best-practise baiting regimes to be implemented for feral cats in the Pilbara.

Future directions

- Regional monitoring will continue, including collection of additional presence records.
- Population genetics for Pilbara northern quolls will be assessed with a further 500 DNA samples to be analysed. This will reveal information about the important northern quoll conservation units, genetic diversity within the region and effective home range size.
- Paternal genetics of northern quoll offspring will be examined, to inform on relatedness and paternity of litter-mates.
- Investigation into the interactions between northern quolls and introduced species (including predators; feral cat, red fox, wild dog, and the invasive cane toad) will continue.
- Characterisation of northern quoll denning requirements, with the view to protecting these key habitat features, or recreating them with artificial habitat.

Conservation of the graceful sun-moth

SP 2010-006

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 in 2016.
- 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 the conservation status of the species 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 appropriateness of its current conservation listing.

Future directions

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

Impact of cane toads on biodiversity in the Kimberley

SP 2006-004

Team

D Pearson

Context

The invasion of cane toads is impacting on the biodiversity of the Kimberley and it appears little can be done to avoid or mitigate their threat. Previous work has identified that predators, such as northern quolls and goannas, are especially vulnerable to poisoning by toads. Research will focus on using taste aversion training to mitigate the impact of cane toads on wild northern quoll and goannas. Monitoring of northern quoll and goanna populations on islands will provide data to understand how these species respond to the recent arrival of toads on islands.

Aims

- Develop procedures to field test taste aversion training as a means to prevent the loss of native predators, especially with northern quolls and goannas.
- Develop techniques to apply taste aversion training should it be successful in inducing predators not to eat toads.
- Monitor quoll and goanna populations on a recently toad infested island (Adolphus) to understand if these populations will persist.

Progress

- Trials of a taste aversion sausages have been undertaken with floodplain goannas with short-term learning leading to increased survivorship of “trained” individuals. Two publications have been produced describing this work.
- Trials of taste aversion sausages were undertaken in Mitchell River National Park in 2015-6 but have been limited by access issues and an unmanaged fire.
- In conjunction with regional staff, surveys and trail camera arrays have been established on Adolphus Island to monitor quoll and goannas populations following the arrival of toads on the 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 collaborative project with the University of Sydney has identified that taste aversion training of floodplain goannas leads to increased survival. The technique could be used to preserve goanna populations at high value conservation sites and on islands that are invaded by cane toads.
- Taste aversion training using toad sausages laced with a nausea-inducing chemical or “teacher toads” leads to short term taste aversion in northern quoll. If longer taste aversion is demonstrated, this will be a valuable technique to protect island populations of susceptible species.

Future directions

- Northern quolls surveys and camera trap arrays on Adolphus Island will be used to ascertain whether northern quolls persist and develop taste aversion in the absence of intervention, such as taste aversion baits.
- Trials with taste aversion baits are proposed to continue at Mitchell River National Park in the north Kimberley to see whether this technique has value in reducing the impacts of cane toads on northern quolls. In particular, research will focus on how long northern quolls remember taste aversion linked to toads and how best to deliver the technique in the field.

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

SP 2003-005

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 continues 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 currently being assessed in bait uptake trials. Bait production is being reviewed with the objective of further improving bait palatability and longevity in the field.
- Feral cat baiting programs on the Fortescue Marsh (Pilbara) has been conducted yearly since 2012. All campaigns have resulted in statistically significant declines in cat occupancy rates in the baiting area.
- 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 fortuitously conducted prior to the Cape Arid National Park wildfire in November 2015 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 Christmas Island has been completed with all domestic cats now desexed, microchipped and registered. Stage 2 of the plan is continuing and involves the removal of all stray/feral cats from residential areas and surrounds. Stage 3 of the plan - island-wide eradication of feral cats, commenced in 2015 and control efforts will continue for the next two years prior to a surveillance period to confirm eradication success.
- Work continues on improving and refining cat lure options.

Management implications

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

Future directions

- Continue refinement of bait medium to improve bait consumption by feral cats.
- Analyse baiting effectiveness at the various research sites and refine the method of operation where necessary to optimise baiting efficacy.

- Further investigation of bait consumption by non-target species and devise methods to minimise risk (e.g. toxin encapsulation).
 - Refine and optimise cat lure options.
-

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

SP 1996-008

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

- The first census of three programmed for 2015-16 of the Mount Gardner population (Two Peoples Bay Nature Reserve, TPBNR) had commenced when a lightning-induced wildfire occurred on 15th November 2015. The fire resulted in >90% reduction of suitable potoroo habitat within TPBNR where the original population had persisted. Seven potoroos were captured and taken into captivity after the fire while a safe translocation site was investigated.
- An investigation of the suitability of Michaelmas Island, near Albany, for this purpose was conducted between January and May 2016 and included flora surveys, sampling of bush rat faeces and analysis of the fungal diet, a trial translocation of two Bald Island animals to Michaelmas Island for four weeks, monitored by trapping, radio-tracking, GPS logging and further fungal diet analysis. Recommendations regarding the transfer of some of the captive potoroos to the island were submitted for approval. Additional captive animals are to be returned to TPBNR.
- A census of the translocated Bald Island population was carried out in July 2015, showing continued decline of the population, falling to 40 from 54 in July 2014. This is an expected adjustment as food resources were depleted following the rapid growth of the population between 2005 and 2012.
- The Waychinicup enclosure potoroo colony was censused twice during the year, and in May, 14 animals were captured. Predation by pythons continues to limit population growth here, despite the addition of over 40 individuals from other sites since 2010 and frequent breeding.
- An updated Recovery Plan for Gilbert's Potoroo was drafted in May 2016 and has been submitted to the Department of the Environment for comment.

Management implications

- The establishment of two insurance populations under the Recovery Program and the earlier development of captive management protocols enabled effective management of potoroos from the TPBNR population that was impacted by fire.
- Further evidence of predation by carpet pythons in the Waychinicup enclosure requires development of python management techniques and approved guidelines.
- Translocation of potoroos to Michaelmas Island and other actions following the fire will require close management of the different colonies to maximise numbers and genetic variability.

Future directions

- Continue monitoring populations at Bald Island and Waychinicup National Park, and survey TPBNR for persisting individuals while monitoring translocated animals. Monitor Michaelmas Island translocation.
- Support intensified fox and feral cat control at TPBNR.
- Evaluate Middle Island (Recherche Archipelago) for suitability as a translocation site for Gilbert's potoroo.

Plant Science and Herbarium

Program Leader: Dave 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, understanding key threats such as *Phytophthora* dieback and weeds, and improving the understanding of genetic and ecological factors that are vital for the long-term viability of plant species. 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.

Is restoration working? An ecological assessment

SP 2016-015

Team

D Coates, M Byrne, M Millar

Context

The recognition of poorly defined success criteria and a lack of long term monitoring have highlighted the need for the development of post implementation empirical evaluations of the quality of restoration activities. This recognition has led to the hypothesis that the most ecologically and genetically viable restored populations will be those where reproductive outputs, plant pollinator interactions, levels of genetic diversity, mating systems and patterns of pollen dispersal most closely mimic those found in natural or undisturbed remnant vegetation. These populations are more likely to persist in the long term and contribute to effective ecosystem function through integration into the broader landscape. This project aims to assess the success of restoration in terms of ecological and genetic viability for plant species in the Fitzgerald River-Stirling Range region of Western Australia, where significant investment is being made in restoring connectivity at a landscape scale.

Aims

- Evaluate levels of genetic diversity for each of six target species, at each of the restoration sites at which they occur and in equivalent remnant reference sites.
- Evaluate mating system parameters for each of six target species, at each of the restoration sites at which they occur and in equivalent remnant reference sites.
- Evaluate patterns of pollen mediated gene dispersal in two proteaceous species.

Progress

- Microsatellite libraries have been constructed for six target species.
- Leaf and seed material has been sampled from *Hakea nitida*, *Hakea laurina*, *Melaleuca acuminata*, *Eucalyptus occidentalis* and *Acacia cyclops* from restored and remnant populations
- DNA has been extracted and primers developed or under development for all five species.

- Analysis of genetic diversity, mating systems and pollination biology is underway for *H. laurina* in restored and remnant populations

Management implications

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

Future directions

- Field work collecting leaf and seed material, and mapping individuals in four restoration sites will continue.
- Genetic and mating system studies will continue on six target species.

Interactive key and taxonomic studies of Myrtaceae tribe Chamelaucieae

SP 2013-052

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

- A paper on *Rinzia* has been submitted to *Nuytsia*.
- Papers on *Babingtonia*, *Hysterobaeckea* and *Malleostemon* (Myrtaceae), *Isopogon* (Proteaceae) and five new species of Cyperaceae have been published in *Nuytsia*.
- Papers on a new subtribal classification of Chamelaucieae and on *Scholtzia* are in preparation.
- Updates have been made to the interactive key to Myrtaceae tribe Chamelaucieae.

Management implications

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

Future directions

- Continue progress towards an official release of the interactive key through publication of an introductory paper in *Nuytsia*.
 - Submit papers on *Scholtzia* and the new subtribal classification (Myrtaceae).
 - Develop keys of Chamelaucieae and Lamiaceae for Keybase project.
-

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

SP 2012-031

Team

N Bougher

Context

This work augments the state's biodiversity knowledge base by creating and applying 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 Parks and Wildlife 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 Western Australian fungi in datasets and as permanent vouchers at the Western Australian Herbarium.

Progress

- Completed 2015 field surveys and associated taxonomic identification studies and submitted survey reports to clients.
- Completed and submitted survey data and vouchers to Western Australian Herbarium.
- Completed analyses of food sources for Gilbert's potoroo recovery program.

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 providing a better basis for assessment of the conservation status of fungi taxa.

Future directions

- Complete the review, editorial and publication processes for monographic book on the Australian Inocybaceae.
- Taxonomic research defining and documenting species of fungi in Western Australian.

- Improve representation and accuracy of data for fungi in the Western Australian Herbarium and in Western Australian Plant Census (WACensus).
 - Fungi surveys in bushlands in conjunction with public community members.
-

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

SP 2012-021

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

- Two scientific manuscripts describing the results of climate manipulation experiments prepared 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, seedling survival, growth and plant survival along with flower and fruit production in mature vegetation;
- increased temperature reduces woody species germination, seedling survival and plant survival in conjunction with canopy health and fruit production in mature vegetation; and
- 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.

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

SP 2012-006

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

- A new and rare species of *Ptilotus* from the Yalgoo bioregion published.
- Paper on a new species of *Eremophila* submitted.
- Paper describing a new species of *Nymphoides* ready for submission.
- *Ptilotus* descriptions for *Flora of Australia* submitted.
- Published article in *Landscape* magazine.

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

- Preparation of further papers describing new taxa in *Ptilotus* and other genera.
 - Further field studies to assist in the resolution of problematic groups within *Ptilotus*.
 - Progress interactive keys to *Ptilotus*, *Gomphrena* and *Swainsona*.
 - Finalise paper dealing with the synonymy of *Adenanthos pungens*.
 - Prepare paper describing a new species of *Hydrocotyle*.
-

The Western Australian Plant Census and Australian Plant Census

CF 2011-111

Team

C Parker, J Percy-Bower, T Macfarlane, K Knight

Context

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

- 559 plant names were added to WACensus, comprising 534 names formally published and 25 informal names.
- 1,231 other edits were made to the census.
- Smut fungi were added to WACensus (92 names).
- WACensus updates were regularly distributed to 245 registered Max users.
- The last major family processed for the APC (Orchidaceae) was progressed and is still ongoing, awaiting compilation of all jurisdictional responses.
- An APC update list is in the final stages of checking and covers changes to a number of taxa in families, including Asteraceae, Cyperaceae, Dilleniaceae, Ericaceae, Euphorbiaceae, Fabaceae, Hypoxidaceae, Lamiaceae, Myrtaceae and Phrymaceae.
- Maintained records of changes to WACensus as a pending contribution of updates to the APC.

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

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

The Western Australian Herbarium's specimen database

CF 2011-110

Team

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

Context

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

Aims

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

Progress

- 9596 records were added to WAHerb, including 1095 Priority Flora and 220 Threatened Flora. The following projects and significant collections were databased: Kimberley Islands Survey, East Kimberley Bush Blitz, Western Australian Museum Marine Survey, Botanic Gardens and Parks Authority, W Muir, R & M Barrett and KA Shepherd.
- Regularly provided customised specimen data requests (species lists and label data) to Parks and Wildlife officers, researchers and the public.
- 56,047 specimen records were edited during this period as part of activities aimed at ensuring the collection is scientifically valid, up-to-date and aligned with the Department's conservation codes.

Management implications

- WAHerb represents the most comprehensive database on Western Australian plants available. 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

- Adding to, timely editing and validation of herbarium specimen records to maintain currency and connectivity between the Herbarium collection, the Western Australian Plant Census (WACensus) and external databases including AVH and ALA.

Herbarium collections management

CF 2011-105

Team

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

Context

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

Aims

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

Progress

- 9,596 specimens were added to the collection, which now stands at 769,256, a 1.26% increase in holdings during this period.
- Loans and exchange: loans outward—17 loans consisting of 881 specimens; loans inward—21 loans consisting of 1,277 specimens; loans returned to the Herbarium—49 loans consisting of 2,060 specimens; loans returned to their home institution—42 loans consisting of 1145 specimens; exchange inward—294 specimens; exchange outward—1303 specimens including 7 requests for destructive sampling.
- Tasks managed by Collections staff with the assistance of volunteers were as follows: mounting and labelling 8,100 specimens; validating the name and occurrence of 2,139 incoming specimens for lodgement; databasing specimens; rearranging fungi collection from a systematic to alphabetic sequence; curating the backlog of algae and slimemoulds; developing a microscope slide collection; curated the *Lepidosperma* collection; assigning Karratha Regional Herbarium specimens to eastern Australian herbaria.
- Volunteer participation was significant, totalling 10,761 hours which is equivalent to 6 full time employees.
- Recruited 28 volunteers through three recruitment drives.
- Maintained the Reference Herbarium facility, which has 14,899 specimens representing 11,764 taxa and also added or replaced 139 specimens. 1,272 visitors used this resource to identify plant specimens during this period.
- Research Collection was accessed by 676 visitors to study taxa or help with identification.

- Provided 282 high resolution scans of herbarium specimens to Parks and Wildlife staff and industry consultants to aid in the identification and location of known and new populations of priority and threatened taxa, and to scientists for research.
- Significant lodgements were processed, including industry surveys, regional Parks and Wildlife surveys, Jurien Wetland Coastal survey, Pilbara Biological Survey, M & R Barrett, T Start (Loranthaceae), and Bushblitz.
- The Herbarium Identification Program provided identifications to a range of clients and specialises in taxa and specimens that clients find challenging. Our most significant clients included Parks and Wildlife, other government agencies, environmental consultancies, regional herbaria and the public. Significant projects this year included Bushblitz, Pilbara DNA barcoding, AusPlots and Karratha Regional Herbarium.
- Educational role continued with staff providing tours of the Herbarium for tertiary institutions, Parks and Wildlife staff, environmental consultancies, community groups and the media.
- Scanned 233 types for the Global Plants Initiative where Western Australian Herbarium type specimens are now accessible to the world's scientific community for study.

Management implications

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

Future directions

- Continue to maintain the collection to an authoritative standard for all users.
- Continue to review and document collections management policy and procedures to effect efficiencies and reflect modern herbarium practices, and where applicable make available on the Herbarium webpage.
- Recruit a sustainable number (approx 20 per year) of volunteers to assist in key Herbarium functions.
- Merge the incoming Manjimup fungi collection with the research collection.
- Work through Parks and Wildlife specimen mounting backlog.
- Physically expand the research collection to improve access, care and maintenance and increase efficiencies in management of the collection.
- Re-house the spirit collection to improve ongoing maintenance and access, and conform with Occupational Health and Safety standards.

Biodiversity informatics at the Western Australian Herbarium

CF 2011-104

Team

B Richardson, K Thiele

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

- *FloraBase* is in a transition to new hardware, as is the entire Western Australia Herbarium IT infrastructure. Most resourcing has been given to facilitating this transition. Once the move is completed a revised presentation of plant, cryptogam and fungi images (via ImageBank) will be introduced to stakeholders.
- Maintenance of *FloraBase* content continued, including key loading, *Nuytsia* updates, and search and login updates.

Management implications

- *FloraBase* allows the community and Department staff to retrieve the most recent information on the name, features, status and distribution of the 13785 currently recognised native and naturalised Western Australian vascular plant taxa. Species conservation and land management efforts across the state are made more effective by access to this authoritative information.
- 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 and maintain the display of all images available from ImageBank
- Upgrade the mapping interface to make better use of Departmental resources, e.g. *NatureMap*
- 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 to species level.
- Complete and release the Specimen Accessioning Tool after a testing phase.
- Develop further standards to facilitate and participate in national and international bio-infrastructure projects, such as ALA, *NatureMap* and other common online services.

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

SP 2011-015

Team

M Hislop

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 collaborative paper with researchers in eastern Australia and the USA is now published in *Australian Systematic Botany*. The paper lays the foundation for the recognition of a greatly expanded *Styphelia* that will encompass all elements of *Leucopogon* not belonging to *Leucopogon s. str.* as well as *Astroloma*, *Croninia* and *Coleanthera*.
- A paper describing a new and probably rare species of *Leucopogon s. str.* from the south-west corner of Western Australia published in *Nuytsia*.
- A paper describing six new species of *Leucopogon s. str.* from the Geraldton Sandplains has been submitted to *Nuytsia*.
- A draft paper with descriptions of five new species of *Styphelia* (currently in *Leucopogon s. lat.*) from the Geraldton Sandplains is near completion.
- A new paper updating the taxonomy of the genus *Brachyloma* is under way.

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 taxonomic resolution of potentially new taxa in *Leucopogon* and *Styphelia s. lat.*

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

SP 2011-013

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

Progress

- Papers on naturalised *Quercus*, *Paspalum* and *Protea* prepared and nomenclature of Declared *Xanthium* species clarified.
- Several new weeds recorded for Western Australia and status of an additional 34 weeds in Western Australia assessed.
- Papers on adding / deleting weeds for Western Australia prepared.
- Paper on weeds on west coast offshore islands published.
- Papers on *Grevillea curviloba* prepared.
- A new weed checklist for the Kimberley has been produced and new priority targets are being prepared.

Management implications

- The Western Australian census will be kept up to date with the deletion of 21 weeds.
- Management of *Typha orientalis* is being completely redesigned as it is now considered a native not an invasive exotic.
- The clarification that *Paspalum vaginatum* is a weedy native and not an introduced alien will result in considerable savings for the management of the Mandora Marsh Ramsar wetland.
- Tall Wheat Grass has been identified as a potentially serious weed of the EPBC listed Temperate Coastal Saltmarsh Threatened Ecological Community in Western Australia and management is required.

Future directions

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

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

SP 2011-002

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 new species was recognised from North West Cape and was added to WACensus as a phrase name.
- 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*.
- A final report is in preparation that provides a taxonomic key to all *Tephrosia* in Western Australia as well as diagnostic descriptions for all informally named taxa, and taxa reinstated or re-circumscribed as a result of this research for which descriptions are currently unavailable or incorrect.

Management implications

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

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.

Taxonomy of selected families including legumes, grasses and lilies

SP 2011-001

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 *Lepilaena*, *Thysanotus*, *Wurmbea*, *Lomandra*, *Neurachne* and *Trithuria*.

Aims

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

Progress

- *Lepilaena* (Potamogetonaceae): a genus of aquatic plants that have been difficult to identify has been studied from all Australian herbarium specimen holdings and species boundaries defined. Paper drafted for one new Western Australia species. Other papers in preparation on pollen structure and variation, and a revision of the genus.
- *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 published on phylogeography of *Trithuria submersa*; paper in preparation on molecular phylogeny and genetic variation in *Trithuria australis*.
- Poaceae: continuing research collaboration on *Neurachne* and the evolution of C4 photosynthesis.
- *Thysanotus* (Asparagaceae): Review of the taxonomy of the twining species, the *T. patersonii* group, with extensive field work, preliminary species defining, and preparation of samples for DNA analysis.
- *Lomandra* (Asparagaceae): field and herbarium work on *L. suaveolens* group.
- Haemodoraceae: paper describing seven new Kimberley species published.
- Asparagales: paper on a neglected taxonomically useful flower feature in several plant families in press.
- Eremosynaceae: book chapter summarising taxonomy and morphology published.

Management implications

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

Future directions

- Complete and submit papers describing new species of *Wurmbea*, *Thysanotus*, *Lepilaena* and *Lomandra*. Conduct appropriate field searches for species or populations that are insufficiently known.
- Continue to revise plant groups and investigate via field and herbarium studies various putatively new species in order to improve knowledge of the flora, provide stable plant names and provide means of identifying species. Current targets are new species of *Rytidosperma* (Poaceae) and reviews of *Arthropodium* and *Lepilaena* in Western Australia.
- Publish information on selected plant groups for general audiences.

Temperature thresholds for recruitment in south-west Western Australian flora

SP 2010-003

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 *Seed Science Research* describing effects of temperature on germination of Western Australian obligate seeding *Banksia* species.
- Paper in press in *Austral Ecology* describing variation in plant functional traits across and within four species of Western Australian *Banksia* along a natural climate gradient.
- Project assessing the impact of long duration, temperature fluctuations on overcoming seed dormancy in common *Acacia* species nearing completion.
- Continuing assessment of the temperature niche for germination in species from the south west of Western Australia focussing on a range of *Eucalyptus* species.

Management implications

- Developing a framework to assess seed viability under environmental change will assist in restoration and land management programs.
- Incorporation of seed biology knowledge into threatened species translocations will increase the opportunities for recovery success.

Future directions

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

Systematics of the triggerplant genus *Stylidium*

SP 2010-001

Team

J Wege

Context

With more than 300 known taxa, the triggerplant genus *Stylidium* is one of the most abundant and diversified genera in Australia. While substantial progress has been made over the past 20 years in documenting Australia's *Stylidium* diversity, our knowledge of the genus remains insufficient for scientific and conservation needs. There are new taxa awaiting formal description, species complexes that remain poorly understood, and a number of nomenclature and typification issues that require resolution. Perhaps the most significant issue at this point in time is the lack of an identification guide and readily accessible diagnostic information for the known species in Western Australia, which hinders accurate identification by conservation personnel, botanical consultants and other stakeholders. This is especially concerning in the south-west region where 86 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

- Two taxonomic papers were published in *Nuytsia* describing six taxa and resolving a number of typification issues.
- Field data and collections for assorted taxonomy, phylogeny and pollination ecology papers were obtained and papers subsequently progressed.
- A contribution was made to the Interim Recovery Plans for the Threatened taxa *Stylidium applanatum* and *S. coroniforme* subsp. *amblyphyllum*.
- Presentations were given at the 2015 Clay-based Wetland Workshop (Swan Region), Australasian Systematic Botany Society Conference (Canberra), and Society Australian Systematic Biologists Conference (Fremantle).

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.

Future directions

- Progress phylogenetic research papers and identification guides.
- Prepare taxonomic papers on focus groups, conducting targeted field work as needed.
- Prioritise field surveys of taxa likely to warrant listing as threatened and prepare threatened flora nominations as required.

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

SP 2009-009

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

- Substantial progress has been made towards finalising the 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/publication in 2016. This book will include descriptions of several hundred species, over 70 of which are new to science.
- Participation in a field survey to Coral Bay, resulted in numerous new collections that have added several hundred specimens to the herbarium holdings. These collections include new species of the red algae *Aphanta* (also representing a new generic record for Australia) and *Kallymenia*, which will be described in the above mentioned book.
- Several additional major papers have been published concerning aspects of the north-western Australian marine flora, including the description of a new genus *Rhytymenia*, based on a species collected from Indonesia in 1899 but not recollected until recent surveys of Ashmore Reef.
- Publication of a paper describing the presence of *Codium tenue*, a rare South African species, in Walpole/Nornalup Inlet.
- 450 new specimens of marine benthic algae have been added to the Herbarium collection.

Management implications

- Easier identification of marine plant species leads to a more comprehensive understanding of their conservation status, recognition of regions with high biodiversity and/or rare species, recognition of rare species, recognition of potentially introduced species, and discrimination of closely-related native species.
- Enhanced knowledge of marine plant species allows a more accurate assessment of management needs and potential impacts of environmental change, including change conferred by resource developments.

Future directions

- Further surveys in 2016-17 of the marine algae of Western Australian including at Coral Bay, the Capes region in the south-west of Western Australia, and sites in the Perth region including Cape Peron.
- 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.

- Prepare a paper describing a new species of the brown alga *Rosenvingea*, collected in early 2016 from Cape Peron.
- Finalise a paper (in collaboration with international colleagues) describing several new genera in the family Kallymeniaceae.

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

SP 2009-008

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

- All of the species descriptions (c. 150) from the book *Algae of Australia: The Marine Benthic Flora of North-western Australia, 1. The Green and Brown Algae* (Huisman 2015) have been edited and 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. This book includes descriptions of over 300 species of red algae, plus higher-level taxa, and descriptions and images of these will be uploaded to *FloraBase* once the book is published.
- Numerous additional *in situ* and microscopic images of marine algae have been taken. Over 100 new images have been uploaded to ImageBank/*FloraBase*.

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 which will permit a more accurate assessment of management proposals/practices and threats to biodiversity.
- Provision of a readily available web-based information system will facilitate easy access by managers, researchers, community and other marine stakeholders to marine plant species inventories and up-to-date names.

Future directions

- Continue preparation and finalize interactive key. 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*.

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

SP 2009-006

Team

J Wege, KA Shepherd, R Butcher, B Rye, T Macfarlane, M Hislop, S Dillon, A Perkins, R Davis

Context

Western Australia has a rich flora that is far from fully known. New species continue to be discovered through the taxonomic assessment of herbarium collections, floristic surveys and the botanical assessment of mineral leases. There are c. 1350 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

- A Threatened *Atriplex* and a rare *Tricoryne* were published in *Australian Systematic Botany*.
- 21 new conservation-listed taxa in the genera *Babingtonia*, *Hibbertia*, *Lasiopetalum*, *Leucopogon*, *Malleostemon*, *Ptilotus* and *Stylidium* were published in *Nuytsia*.
- A further 50 new species (of which 41 are conservation-listed) were published in a special issue of *Nuytsia* as a result of a collaboration between the Botanic Gardens and Parks Authority and staff and research associates of the Western Australian Herbarium.
- Nine phrase-named taxa under *Dampiera*, *Goodenia*, *Leucopogon*, *Philotheca*, *Scaevola*, *Senna*, *Stylidium* and *Vigna* were found to be synonymous with known species. Papers recommending their removal from WACensus (and in several cases the *Threatened and Priority Flora list for Western Australia*) were published in *Nuytsia*.
- *Ricinocarpos* Eastern Goldfields (A. Williams 3), a putative new species from mineral leases in the Coolgardie region, was added to WACensus and the *Threatened and Priority Flora list for Western Australia*.
- Papers describing new, conservation-listed species of *Allocasuarina*, *Cochorus*, *Dysphania*, *Lasiopetalum*, *Leucopogon* and *Tetralochea* and *Trachymene* have been progressed.

Management implications

- The provision of names, scientific descriptions, illustrations and associated data will enhance the capacity of conservation and industry practitioners to identify new species, thereby improving species management, conservation assessments and land use planning.

Future directions

- Identify and formally describe new taxa of conservation significance.
-

Development of interactive identification platforms and content

SP 2007-014

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 *FloraBase*, 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*.
-

Genetic and ecological viability of plant populations in remnant vegetation

SP 2002-001

Team

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

Context

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

Aims

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

Progress

- Analysis of the genetic diversity, mating system and reproductive biology of *Hakea oldfieldii* has been completed. One paper has been published in *Biological Journal of the Linnean Society* and another paper has been accepted in *Ecology and Evolution*. The three population areas in Perth Hills, Busselton and south coast showed significant genetic divergence as expected but there was also significant population divergence within these areas indicating low historical connectivity. Low diversity is associated with historical processes rather than recent fragmentation. Populations were predominantly outcrossed even when severely reduced in size, indicating little effect of inbreeding in small populations, but reproductive parameters were higher in small populations with intact vegetation compared to disturbed sites, highlighting effects of understorey on pollinator abundance and behaviour.
- Analysis of reproductive output, mating system variation, progeny fitness and genetic diversity in relation to habitat fragmentation has been completed for *Eucalyptus wandoo*. A paper is in the final preparation stage. Higher levels of soil electrical conductivity were strongly associated with greatly reduced fruit set, suggesting significant sub-lethal effects of secondary soil salinity on reproduction. Levels of pollination were surprisingly high in small populations but probably involve high levels of self-pollination, leading to low seed set in small populations. Seedling survival in a shadehouse trial was higher for populations that had a higher edge to area ratio, which may be attributed to increased nutrient availability in the agricultural matrix.
- Analysis of reproductive output, mating system variation, progeny fitness and genetic diversity in fragmented populations of *Eremaea pauciflora* is close to completion.

Management implications

- The ability to rapidly and accurately assess the conservation value of a vegetation remnant is a critical step in landscape management aimed at integrating the goals of conservation and agricultural production. Currently much of this assessment is based on best guesses using anecdotal species-specific evidence, on the general principle that bigger is better, and on simple presence and absence data that take little account of long-term remnant trajectories. Improved accuracy of assessment of long-term persistence

of broad classes of plant species will facilitate improved prioritisation of remnants for conservation and therefore better allocation of limited management resources.

- Establishment of realistic empirically-based goals for remnant size, shape and landscape configuration that maximise regional persistence of plant species will allow more efficient conservation efforts at the landscape level by facilitating cost-benefit analyses for remnant management and restoration work.
- The *H. oldfieldii* study showed that conserving populations in intact habitat is a high priority to maintain the genetic and ecological processes in naturally fragmented and insular species. Management interventions, such as enrichment planting to increase the diversity of pollen donors, should also include habitat and understorey restoration to facilitate effective mating patterns. Seed collection should prioritise populations with intact habitat to maximise genetic diversity.
- Levels of secondary soil salinity should be assessed and monitored in high-value vegetation remnants in agricultural landscapes. The *E. wandoo* study revealed that low to moderate levels of soil salinity can have highly significant sub-lethal effects on reproductive output, which are likely to translate to reduced population viability.

Future directions

- Prepare papers on mating system variation and reproductive output in *E. pauciflora* and genetic diversity in *Calothamnus quadrifidus*.
- Finalise papers on genetic diversity, pollen dispersal, mating systems, reproductive biology and demography in *Banksia nivea* ssp. *uliginosa*.
- Finalise paper on reproductive output, mating system variation, progeny fitness and genetic diversity in *E. wandoo*.

Translocation of critically endangered plants

SP 2001-004

Team

L Monks, R Dillon, D Coates

Context

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

Aims

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

Progress

- Infill planting was completed for translocations of two Critically Endangered plant species at two sites.
- Monitoring was undertaken for 44 sites of 31 taxa translocated in previous years.
- Detailed demographic monitoring was undertaken for *Acacia cochlocarpa* subsp. *cochlocarpa* at translocation and natural sites, and demographic monitoring will be used to develop a Population Viability Analysis (PVA) model for this subspecies.

- Drafting of two publications on flora translocation methods and success criteria continued.
- Assisted Departmental District and Regional staff plan and implement a range of flora translocations.
- Provided advice to Departmental staff on flora translocations proposals submitted for approval.
- Seed collections for mating system studies were completed for two translocated populations of *Banksia brownii*.

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, leads to greater translocation success.
- Further development of success criteria and methods for analysing long-term success, such as the use of PVA, mating system analysis and genetic variability analysis, will ensure completion criteria are adequately addressed and 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 enables this information to be used immediately to inform other flora translocation projects.

Future directions

- Continue the planting of experimental translocations of Critically Endangered and other Threatened flora where further translocations are deemed necessary.
- Continued monitoring of 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 and success in Western Australia.
- Publish paper on translocation methods and *Lambertia orbifolia* PVA study.
- Continue data collection for development of a PVA model for translocated and natural populations of *A. cochlocarpa* subsp. *cochlocarpa*.

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

SP 2001-001

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 published 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 due to *Phytophthora* dieback.
- Seed has been extracted from collections from two translocated *B. brownii* populations and seven natural populations to assess mating system variation and benchmark mating system performance in the translocated population.
- Data on mating system variation in two sister triggerplant species (*Stylidium affine* and *S. maritimum*) with contrasting breeding systems is currently undergoing re-analysis.

Management implications

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

Future directions

- Complete data analysis and draft paper on the mating system in two *Stylidium* species, *S. affine* and *S. maritimum*.
- Commence mating system and genetic diversity studies on *B. brownii* translocated and natural populations.
- Carry out seed collections from translocated and natural populations, and commence genetic diversity and mating system studies on *L. orbifolia* translocated and natural populations.

The population ecology of critically endangered flora

SP 2000-015

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

- Continued monitoring the demography of the Critically Endangered *Verticordia staminosa* subsp. *staminosa* in relation to a drying climate in south-west Western Australia
- Collected and compiled micro-climate sensor array taken from 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.
- A paper on fire response of threatened flora in the south west has been finalised and will be submitted to *Biodiversity and Conservation*.
- Undertaken analysis of range size in Threatened and Priority shrub species in the south west to better understand possible extinction debt.

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 *Phytophthora cinnamomi* and recent fire regimes. Using the International Union for Conservation of Nature (IUCN) Ecosystem Risk Assessment criteria this 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 the fire response of threatened flora and the development of fields in the threatened and Priority Flora database will assist in the design an delivery of improved fire management protocols for threatened flora.
- The analysis of extinction debt in the highly fragmented south west landscape will further assist in the development of protocols for prioritising threatened flora for management intervention and recovery actions.

Future directions

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

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

SP 1999-010

Team

A Cochrane, A Crawford, A Monaghan

Context

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

Aims

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

Progress

- A total of 202 seed collections representing 107 species were accessioned into the Threatened Flora Seed Centre in the past year, of which 46 collections (29 species) were Critically Endangered.
- 283 accessions representing 216 Declared Rare Flora collections (80 species), 31 Priority species and 36 common species were banked.
- Duplicates of 40 collections were sent to Millennium Seed Bank Kew as a risk management strategy.
- 353 accessions from the *Banksia* Woodland Restoration Project in the Swan Region were stored, with 171 of stored collections being removed for use in direct seeding.
- 66 germination tests were conducted.
- Provision of seedlings of six Critically Endangered species for translocation.
- The seed bank now contains collections of 330 Threatened flora, 704 Priority flora and 810 key restoration species.

Management implications

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

Future directions

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

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

SP 1998-003

Team

M Byrne, D Coates, N Gibson, B Macdonald, M Hankinson, KA Shepherd, R Butcher, K Thiele

Context

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

Aims

- Provide genetic information for the conservation and management of Western Australian flora, especially rare flora.
- Determine the level of differentiation 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.

Progress

- Analysis of AFLP markers for putative taxa of *Synaphea* from the Pinjarra Plain has identified genetic discontinuities between populations to inform taxonomic revision.
- Analysis of genomic data in the *C. quadrifidus* species complex is in progress to support taxonomic determinations.

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 phylogeographic patterns in *C. quadrifidus* has informed taxonomic revision of the group.
- Resolution of the taxonomic status of *P. scabra* subsp. *dendrotricha* (previously *Pityrodia* sp. Yilgarn) has enabled conservation assessment as Priority Three taxon, as it is known from several populations that are not under immediate threat.
- Clarification of taxonomic status of *Platytheca* sp. Sabina, *H.* aff. *prostrata*, and *H. scutellifera* and associated taxa will enable evaluation of conservation status and implementation of conservation actions, if required.

Future directions

- Taxonomic revisions of *Platytheca* sp. Sabina, *H.* aff. *prostrata*, and *H. 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, the Bureau of Meteorology, other government and private sector research providers and the corporate sector.

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

SP 2015-009

Team

C Munday, M Byrne

Context

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

Aims

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

Progress

- The Invasiveness and Impact question sections of the WRA have undergone extensive review and a final draft has been completed, supported by documentation outlining the environmental risk strategy.
- Methodology for the assessment of potential distribution has been reviewed and a discussion document prepared outlining the issues involved. A number of protocols are under consideration.
- The Invasiveness and Impact sections of five WRAs for non-indigenous species with possible potential in pastoral systems have been completed. Some protocols for potential distribution maps have also been trialled

Management implications

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

Future directions

- A final review of the Invasiveness a Impacts sections of the WRA will be completed.
- Selection of methodologies will be completed and final protocols proposed to determine the potential distribution, where required, for weed risk assessment.
- Additional WRAs for species under consideration for introduction will be prepared and reviewed by a technical committee of weed and agricultural experts.
- The outcomes of the project including WRAs and their supporting framework will be widely disseminated to stakeholders, decision makers and the general public.

Understanding the changing fire environment of south-west Western Australia

SP 2014-001

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

- Preliminary analysis of trends in the Soil Dryness Index from 2000 to 2014 suggest that the duration of the peak dryness period when the Index exceeds 150 mm has increased by up to 30 days in the southern forests represented by Bridgetown and Pemberton observation sites. Observations from Pearce, Bickley and Rocky Gully show a reduced number of days in the peak dryness range. These trends would be explained by change in the spatial pattern of summer rainfall.
- The spread and behaviour of the Waroona bushfire in early January 2016 was reconstructed in order to identify significant fuel and weather factors that influenced the behaviour of the fire during different phases of its spread. Findings were presented to the Waroona Special Bushfire Inquiry in April 2016. Fire behaviour data have been made available to the Bushfire and Natural Hazards Cooperative Research Centre for a project on coupled fire-atmosphere modelling, and for a national project evaluating the performance of bushfire simulators.
- In conjunction with Warren Region and Fire Management Services Branch, an adaptive management program has been developed to facilitate and evaluate prescribed burning in young regrowth stands of jarrah and karri. Achievement of prescribed burning objectives is being monitored using ground-based methods and assessment of burn severity derived from satellite remote sensing, and where possible linked to existing Forestcheck monitoring.

Management implications

- Understanding the factors that influence the location and timing of bushfire ignitions is important for developing effective management strategies to minimise the risks posed by unplanned fires, and to guide the level of resourcing required for bushfire suppression in different management areas. Lightning is an important cause of bushfire ignition in south-west Western Australia and the area burnt by lightning-caused fires has been disproportionately large relative to the number of ignitions during the past decade. Better understanding of the links between climatic patterns and lightning ignition could provide advance warning of above-normal activity and the opportunity for improved preparation and resource deployment.
- The increased occurrence of large and damaging bushfires in the past five years has led to a re-focus on the importance of managing fuels with prescribed fire. In order to achieve a safe and effective prescribed burning program there is a need to understand how weather and climate influence opportunities for burning, and how these opportunities may be changing over time.

Future directions

- Finalise and submit a manuscript analysing temporal and spatial patterns of lightning ignition for the Warren Region, and continue to investigate climatic factors associated with lightning ignition.
- Further analyse data to investigate trends in fuel moisture content and soil dryness during the past 30 years.
- Prepare a manuscript examining weather and fire behaviour during the Waroona bushfire in collaboration with co-authors from the Bureau of Meteorology.
- Monitor and report on the outcomes of the adaptive management trial of prescribed burning in regrowth forest.

Restoring natural riparian vegetation systems along the Warren and Donnelly Rivers

SP 2013-004

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

- Analysis of genomic data has found the three species (*Astartea leptophylla*, *Callistachys lanceolata*, *Taxandria linearifolia*) to have different patterns of genetic structure across the climate gradient. *Astartea leptophylla* is restricted to the main river and was found to have the lowest levels of differentiation between populations. *Callistachys lanceolata*, a widespread species with short distance dispersal had high levels of genetic structure between populations. This data will be used to determine genetic adaptation between populations and climate zones of the three species.
- Initial outlier analysis has found the *Astartea* to have low numbers of outliers (97) and the majority are under directional selection.
- *Callistachys* was found to have a similar number of outliers (96) but two-thirds of these are under balancing selection.
- *Taxandria* with moderate levels of genetic diversity between populations was found to have high numbers of outliers (264) with three-quarters of these under directional selection.
- Experimental plantings were impacted by insect damage and have been replanted this year with insect exclusion measures in place.
- A manuscript detailing a spatially explicit approach to support decision making for seed provenance selection in ecological restoration in a climate change context has been revised and submitted for publication.

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

- Complete analysis of association between allele frequencies of outlier loci and ecological variables to reveal specific significant climatic associations and how these are related to genetic structure and gene flow.
- Identify the scale of climate associations and the implications of these for seed sourcing with the aim of maximising resilience in restoration projects.

- Sample from experimental plantings of *Callistachys* for genomic analysis to assess establishment and performance and to determine any effects of adaptation to drier environments on current performance of germplasm in revegetation projects
 - Prepare manuscripts on genetic structure and outlier identification for all three species.
-

Responses of terrestrial vertebrates to timber harvesting in the jarrah forest

SP 2012-038

Team

A Wayne, C Ward, M Maxwell

Context

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

Aims

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

Progress

- Spotlight monitoring on three standardised transects was maintained at six repeat surveys per transect per year (three surveys each in spring and autumn).
- Ngwayir (western ringtail possum) populations in the greater Kingston area remain extremely low having declined to almost undetectable levels between 2001 and 2013. Spotlight detections increased slightly in 2014 and this trend has been sustained.
- Koomal (common brushtail possum) populations remain abundant.
- Data from this study form the basis for a manuscript currently in review that indicates seven species have declined in succession in the Upper Warren region since 1994 (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 (koomal, chuditch and tammar wallaby).
- A paper examining the response of the woylie to timber harvesting in jarrah forest was published in *Forest Ecology and Management*.

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 is of serious concern requiring action, especially given the high conservation value of the area and the importance of the populations supported including the species already mentioned (dunnart, native bush rat, ngwayir wambenger, quenda, woylie and western brush wallaby) and others such as the numbat, tammar 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

- Responses to timber harvesting of medium-sized mammals will be analysed and prepared for publication.
-

Fire behavior and fuel dynamics in coastal shrublands

SP 2012-036

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 during planned burning operations.
- Collaboration with Blackwood District to develop an adaptive management framework for a planned burn at Boranup that includes coastal heath and mixed shrubland.
- Fire behaviour during the Two Peoples Bay bushfire has been documented and is currently being used to validate existing fire rate of spread models.

Management implications

- Development of a systematic approach to describing fuels and predicting fire behaviour in coastal shrublands will permit the implementation of better informed fire management programs in this habitat.
- Improved knowledge of factors determining fire behaviour in shrublands will contribute to more effective training programs for fire managers and fire-fighters from the Department and other organisations with responsibility for fire preparedness, management and suppression.

Future directions

- Collect fire behaviour metrics from planned burns as these are implemented.
 - 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.
-

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

SP 2012-029

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

- Burning treatments were undertaken at the McCorkhill block experimental site in Autumn 2016.
- Data analysis has commenced and patterns of plant community response have been identified.
- Knowledge and understanding gained from this long term study has been incorporated into a fire ecology training program that will be delivered to employees involved in fire management planning and operations. Training was provided to participants in the Department's Fire Management Development Program in June 2016.

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.

North Kimberley Landscape Conservation Initiative: monitoring and evaluation

SP 2012-027

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 in its sixth year. A total of 92 sites have been surveyed for mammals and vegetation at least once and 112 sites for vegetation only. Ten rainforest sites have been surveyed at least once. Sites at Mirima National Park, Mitchell River National Park, King Leopold Range National Park, Prince Regent National Park, Drysdale River National Park, Bachsten Creek and Mount Elizabeth have all been sampled at least twice.
- Data from monitoring sites, combined with spatial data, 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.
- 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. King Edward River, Drysdale River and Mount Elizabeth have the lowest mammal abundance/richness and are localities of greatest conservation concern.
- Mammal abundance and richness has increased at the Mitchell Plateau compared with earlier surveys. 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.
- Surveys at Mirima have revealed a declining mammal abundance trend since 2012 when much of the Park was burnt by a large wildfire. Mammal abundance remains low despite sufficient time for re-establishment of mature vegetation structure.

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 be maintained and expanded in important conservation reserves.
- There is 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 has benefited 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 maintained to enhance conservation values.
- 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.

Future directions

- Monitoring and evaluation will continue so that the effectiveness of management interventions can be evaluated in the longer term.
- Evaluation of factors influencing mammal abundance and richness between years will be undertaken using a statistical modelling approach.
- 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.
- A collaborative project with Charles Darwin University studying the abundance and habitat requirements of arboreal mammals in the North Kimberley will commence in 2016/2017.

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

SP 2012-002

Team

M Byrne, C Yates, B Macdonald, R Binks, L McLean

Context

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

Aims

The project will test the following alternative hypotheses:

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

Progress

- Analysis of genomic variation and environmental traits in nine populations across a climate gradient has been completed in *Eucalyptus loxophleba* with evidence of 50 outlier markers associated with climate adaptation.
- A paper describing the genomic architecture of climate adaptation in three species, *E. salubris* and *E. loxophleba* from Western Australia and *E. tricarpa* from Victoria has been written and is in review.
- To further explore geographic patterns in the two genetic lineages detected in *E. salubris*, 13 additional populations have been collected across the species' distribution and genomic sequencing completed. The raw genomic data is currently under analysis.

Management implications

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

Future directions

- Complete final scientific paper on the genomic architecture of adaptation.
- Complete analysis of lineage divergence in *E. salubris*.

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

SP 2011-020

Team

L McCaw, G Liddelow, R Mazanec

Context

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

interactions with pests and pathogens, and increased recognition of the role of forests in maintaining global carbon cycles.

Aims

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

Progress

- The scope of this project has been broadened to include thinning response of even-aged jarrah stands, with all thinning experiments now covered by a single project plan.
- The thinning experiment in 100 year old regrowth jarrah forest at Inglehope block near Dwellingup was burnt by mild prescribed fire in October 2015 with minimal crown scorch to codominant trees. Following the burn, plot boundaries were re-marked and damaged tree tags replaced in order to maintain the integrity of the experimental site in the longer term.
- Re-measurement of tree diameter and bark thickness was completed on seven plots in the Inglehope experiment.

Management implications

- Thinning concentrates the growth potential of a site onto selected trees and provides forest managers with options to manage stands for particular structural characteristics that may be important for future yield of wood products, wildlife habitat or resilience to disturbance. Thinning is also an important tool for managing streamflow and groundwater levels in forested catchments in the face of a drying climate.
- Tree mortality associated with *Armillaria* root disease appears to reduce in older karri stands, and small gaps created by dead trees become less obvious as stands mature. Localised tree mortality can be regarded as a natural process and is likely to contribute to patchiness in the mature forest. However, the extent of tree mortality in silviculturally managed stands should be monitored to ensure that stand productivity and other forest values remain within acceptable ranges.

Future directions

- Finalise re-measurement of diameter and bark thickness at the Inglehope experiment (23 plots).
- Analyse and report on trends in tree and stand growth at Inglehope, with a focus on links between climate and growth.
- Analyse trends in the incidence and severity of *Armillaria* root disease at Warren block since 2000.

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

SP 2011-019

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 2015/16 GLS population level. Populations indicative of severe defoliation were present in areas around Donnelly Mill north west of Manjimup.
- A paper investigating climate effects on GLS outbreaks was prepared and submitted to *Austral Entomology* and is currently being revised after referee comments.
- A preliminary study was initiated investigating effects of understorey removal by fire on pheromone trap catch. Catch data have been summarized and analyzed. Dense understorey interferes with pheromone trap effectiveness. Fire enhances trap catch in forest with a dense understorey by removing the shrub layer. Testing for a vegetation effect using a dryness index as a proxy for vegetation density showed negligible impact on the historical data from long term GLS population monitoring sites.

Management implications

- Integration of GLS population and impact data from two major outbreak events indicates a strong relationship between GLS outbreak and periods of below-normal rainfall at seasonal or longer timescales. Further outbreaks are likely given present declining trends in rainfall.
- Pheromone trapping is effective in monitoring GLS populations and could be used routinely to identify the likelihood of GLS outbreak. Moth populations are a good predictor of subsequent larval populations and may provide early warning of outbreak events in the context of climate data.
- Interference with pheromone based mate finding by vegetation has implications for moth species richness at landscape scales because pheromone based mate finding is common in moths (including other eucalypt defoliators). Understanding drivers of moth richness may allow spatial predictions of moth species richness and enhance understanding of effects of global change on moth biodiversity.
- Vegetation density and structure as well as species composition and fire regimes in jarrah forest has implications for rate of spread and control of potentially invasive and exotic moth species which use pheromone based mate finding.

Future directions

- Continue pheromone trapping at long-term monitoring sites.
- Prepare a manuscript describing fire and vegetation density effects on the efficacy of GLS pheromone trap catches.

- Investigate vegetation species composition and fire effects at different trap heights using the GLS pheromone system.
 - Finalize edits and publish paper describing relationship between long term GLS population and climate cycles.
-

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

SP 2011-011

Team

C Yates, M Byrne, S Tapper

Context

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

Aims

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

Progress

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

Management implications

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

Future directions

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

Fire regimes and impacts in transitional woodlands and shrublands

SP 2010-011

Team

C Yates, C Gosper

Context

The Great Western Woodlands (GWW) is an internationally significant area with great biological and cultural richness. This 16 million hectare region of south-western Australia arguably contains the world's largest and most intact area of contiguous temperate woodland. The GWW Conservation Strategy and a review conducted by a wide range of scientists with expertise in the region each identified inappropriate fire regimes as a threat to the woodlands and emphasised the need for a science-based fire management regime for the area. Critical gaps in the knowledge of fire ecology for GWW ecosystems are a major hindrance for ecological fire management in the region. The GWW supports eucalypt woodlands at very low mean annual rainfall (250-350 mm). 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, with sampling of plant composition, vegetation structure, visual fuel assessment, ants and birds.
- Plant data from the chronosequence have been used in national-scale synthesis of: (i) the spatial and vegetation type distribution of fire response traits in woody plants (published in *Science of the Total Environment*); (ii) fire regime and environmental correlates of fire response traits (in preparation); (iii) how Western Australian eucalypt woodlands differ in fire ecology from eastern Australian analogues (*Journal of Biogeography*); and (iv) the composition, biogeography, environmental correlates and ecology of Australia's temperate woodlands (in review for the book *Australian Vegetation*).
- Alien plant records from the GWW were used to identify environmental and disturbance predictors of weed occurrence, and priority weed species for preventative weed management in a climate change context (published in *Biodiversity and Conservation*)

- Gimlet tree size was sampled at 100 plots systematically located across the GWW to estimate stand-class structure, and via linking with models estimating tree age from tree size, woodland age-class distribution.
- Methodology to sample tree and shrub, woody debris and litter carbon pools was tested at pilot sites.

Management implications

- National-scale syntheses of temperate eucalypt woodland fire ecology revealed that Western Australian woodlands are uniquely dominated by taxa that are obligate seeding or recolonise after fire from unburnt populations, and have vegetation dynamics driven by rare, stand-replacing disturbances. These characteristics illustrative a putative vulnerability to decreases in intervals between fires.
- Post-fire succession in plant composition and structure, which in turn determines successional patterns in animals, occurs over multi-century timescales, demonstrating the value of avoiding fire in mature woodlands to maximise future fire management options.
- Changes in vegetation structure, cover and hazard indicate maximum gimlet woodland flammability at intermediate times since fire, supporting the revision of fire behaviour ratings.
- Contemporary invasive plant spread in the GWW could be reduced via: (i) targeting abandoned and current settlements for removal of disjunct weed populations; (ii) minimising new settlement creation in locations currently remote from towns; and (iii) closing water points on conservation estate to reduce disturbance-induced weed recruitment. Considering future climate tolerance in weed species prioritisation results in a feasibly small selection of taxa for pre-emptive regional-scale eradication or containment.
- GWW woodlands have little grass in comparison to other temperate woodlands. If perennial grass weeds (such as buffel grass) become widely established, potentially facilitated by climate change, substantial fire regime shifts and subsequent loss of mature woodlands are plausible.
- Knowledge generated through this project has been incorporated into eucalypt woodland fire ecology training, to be delivered to Department of Parks and Wildlife staff.

Future directions

- Refine models estimating the time since fire of long-unburnt gimlet woodlands through the use of the growth ring increment data.
- Use refined age-size models and stand structure data 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.
- Complete measurement of carbon pools across the gimlet chronosequence to determine the role of fire management in carbon sequestration.

Identification of seed collection zones for rehabilitation

SP 2006-008

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

- Papers on population genetic structure and phylogeographic patterns in *Kennedia coccinea* and *Bossiaea ornata* have been published.
- Analysis of microsatellite variation and cpDNA variation in *Allocasuarina humilis* has been completed and a paper has been accepted for publication.
- Analysis of microsatellite variation and cpDNA variation in 28 eight populations of *Banksia sessilis* has been completed and drafting of a paper has progressed.
- Analysis of nuclear genetic variation and cpDNA variation in marri (*Corymbia calophylla*) has been completed and a paper is being prepared.

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

Future directions

- Complete publication of papers on genetic analysis of phylogeographic patterns and genetic structure, and seed sourcing strategies for *B. sessilis*.
- Complete publication of papers on genetic analysis of *C. calophylla* and identify seed collection recommendations.

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

SP 2006-003

Team

L McCaw, J Farr, G Liddelow, V Tunsell, B Ward, A Wills

Context

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

Aims

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

Progress

- A progress report on monitoring undertaken in Blackwood and Perth Hills Districts during 2014 was finalised, following the completion of specimen identification and curation.
- Work continued on the preparation of scientific papers reporting the second round of monitoring completed between 2007 and 2012. These papers will examine changes in species assemblages between the first and second rounds of monitoring in relation to climatic factors, changes in forest structure and improved sampling methods.
- Work continued to review the capacity and process for delivering integrated forest monitoring into the future.
- Seven monitoring grids in Wellington District burnt by the large Lower Hotham bushfire in February 2015 were re-sampled. Invertebrate pitfall and light trap sampling was undertaken in spring 2015 and autumn 2016 on burnt sites. Monthly inspections to identify vascular plant species in flower have revealed a number of species not recorded previously at these grids, including a significant range extension and a potential new species. Crown recovery of overstorey trees on burnt grids was assessed in November 2015.
- An analysis of factors affecting the consumption of coarse woody debris was undertaken using data gathered from 20 monitoring grids burnt by prescribed fire and bushfire.
- Stand structure and fuel load were re-sampled in the Nalyerin block external reference grid which is in a fire exclusion reference area last burnt in 1987. Fuel load has been sampled previously at this grid in 2005 and 2011.

Management implications

- Forestcheck provides a systematic framework for evaluating the effects of current silvicultural practices across a range of forest types and provides a sound basis for adaptive management. Sixty five monitoring grids have now been established, with 50 of these sampled at least twice.
- Findings from the project continue to inform a variety of forest management policies and practices and have been incorporated in periodic revision of silvicultural guidance documents. Monitoring data have been used to verify predictive models for forest growth and species occurrence.
- The network of Forestcheck grids also provides a framework for monitoring responses to random disturbance events such as bushfires and extreme droughts, and for examining the impacts of a changing climate over the longer term.

Future directions

- Finalise analysis of data from the 10-year monitoring period (2002-2012) and publication of 10-year results.
- Review monitoring protocols and incorporate new techniques where these will improve efficiency and quality of data collected.
- Prepare manuscripts reporting on consumption of coarse woody debris and the initial response of vascular plants and invertebrates following the 2015 Lower Hotham bushfire.

Burning for biodiversity: Walpole fine-grain mosaic burning trial

SP 2004-004

Team

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

Context

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

Aims

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

Progress

- Field work has been completed for this project. Data are being compiled, fungi and invertebrate collections have been sorted and documented. Data for invertebrates has been compiled, and analysis has commenced.
- 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* was published in *Fire Ecology*.
- Prescribed burning was undertaken in London block and the western half of Surprise blocks in spring 2015 as part of the Warren Region prescribed burn program. The resulting pattern of burn severity has been determined from Landsat imagery and is being examined in relation to the fuel age mosaic established during the project.

Management implications

- This study demonstrates that fine-grain patch-burning is operationally feasible in forest areas. Although data analysis is incomplete, benefits to biodiversity at the landscape scale, especially invertebrates and fungi, are increasingly evident. Any benefits to higher order organisms may take longer to emerge. Large-scale implementation of mosaic burning by the frequent introduction of fire into the landscape is being considered 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.
- Develop recommendations for mosaic burning.

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

SP 2003-004

Team

N Burrows, G Liddelow

Context

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

Aims

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

Progress

- Aerial cat baiting was carried out on Matuwa in July 2015 as part of the Western Shield and Rangelands Restoration programs. To measure the effectiveness of baiting, remote cameras were used in conjunction with traditional track counting as part of a program to move predator surveys to using remote cameras only. Baiting was moderately successful with the cat track activity and camera activity indices showing reductions due to baiting of 50% and 60% respectively, resulting in a post-bait cat track activity index <10. This trial demonstrated that cameras can be reliably used to survey cat density and are a significant cost saving. The track activity index in the unbaited control (Earaheedy - Kurara Kurara) was 26, indicating that cat control continues to be successful on Matuwa.
- The Mulgara (*Dasycercus blythii*) population on Matuwa has declined, but is still significantly higher than before baiting commenced in 2003 and is about double the population on the nearby unbaited Kurara Kurara.
- The Matuwa fire management plan continued to be implemented, including further installation of fuel-reduced buffers around some fire management cells and core ignition using aircraft. Some small patch-burning was carried out inside the predator-proof compound for wildfire mitigation and to create habitat diversity.

Management implications

- This project is providing insurance populations of threatened arid zone mammals.
- Information will inform guidelines for the proactive management of fire in the arid zone rangelands to reduce the severity (scale and intensity) of wildfires and to provide habitat choice through mosaic burning.

- Guidelines for controlling introduced predators in the arid zone rangelands will reduce this threat to native fauna. Reintroduction and protection of mammals of the arid zone rangelands, other extant fauna, vegetation and other elements of the biota will provide reconstruction of animal and plant assemblages in an arid zone ecosystem.
- A framework and protocol for assessing and reporting trends in ecosystem condition in arid zone rangelands will provide a basis for ecosystem condition monitoring.
- Future monitoring of cat density and baiting effectiveness on feral cats can be achieved through the use of cameras alone, delivering a significant cost saving for management.

Future directions

- Assess and report on the effectiveness of wild cat and dog baiting to be undertaken in July 2016.
- Prepare a paper for publication reporting on 10 years of biodiversity monitoring on Matuwa.
- Survey wild dogs, cats and mulgara on Karara Karara where there has been no introduced predator control, and compare results with Matuwa.
- Continue to implement the fire management plan including buffer burning and aerial patch burning. Carry out patch-burning in the predator-proof compound.

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

SP 2001-005

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 has been verified and arranged for analysis using non-metric multidimensional scaling ordination approaches.

Management implications

Previous 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 invertebrate 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 of the jarrah forest is likely to have a greater effect on invertebrate species composition than disturbance at such a scale in upland jarrah forest.

Future directions

- Complete data analysis and prepare a manuscript for publication.

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

SP 2000-003

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) and Wuraming (control) catchments.
- The corroded mild-steel V-notch weir plate in Yarragil 4X (treated catchment) was 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 has been prepared.
- Groundwater bores were relocated in experimental catchments at Iffley and Sutton forest blocks in the Warren Region. Water levels have been measured in some bores, but further maintenance and repair is required before all bores will be measurable.

Management implications

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

Future directions

- Continue monitoring of groundwater levels, streamflow, stream salinity and turbidity and rainfall.
- Re-measure forest density along fixed transects in Yarragil 4X and 6C to determine the forest regeneration response to the timber harvest and silvicultural treatments.
- Re-measure tree growth in Yarragil 4L to determine the long-term hydrological response to thinning, and prepare a manuscript for publication.
- Examine the feasibility of a second thinning in Yarragil 4L, 35 years after the previous thinning, with a view to informing the impacts of silviculture practices on water production.
- Review the network of existing groundwater bores to identify those bores which should be monitored to inform KPI 10 of the *Forest Management Plan 2014-23*.

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

SP 1998-007

Team

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

Context

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

Aims

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

Progress

- A paper on genetic patterns in *Acacia ancistrocarpa* and *A. atkinsiana* has been submitted for publication. *Acacia ancistrocarpa* has moderate haplotype diversity with most populations showing specific haplotypes. Nuclear diversity was moderate with little genetic structure across the Pilbara populations of this widespread species. In contrast, the Pilbara endemic, *A. atkinsiana* had low haplotype diversity with little geographic structure. Nuclear diversity was low and genetic differentiation among populations was moderate.
- A paper on genetics patterns in *Eucalyptus leucophloia* has been submitted for publication. This species shows genetic signatures of the Hamersley Range being a historical refugium, supporting a previous hypothesis of inland ranges being refugia in the Australian arid zone.
- A paper on the genetic diversity and differentiation in the rare *Aluta quadrata* has been submitted for publication. The species shows high nuclear genetic differentiation but no chloroplast haplotype variability indicating that the geographic separation of the three species locations is leading to contemporary genetic differentiation but is not a result of historical isolation.
- Studies have commenced on another eight species in the Pilbara for the identification of seed collection zones. Collections and microsatellite genotyping have been completed for all eight species, *Petalostylis labicheoides*, *Indigofera monophylla*, *Senna glutinosa*, *Corymbia hamersleyana*, *A. pruinocarpa*, *A. hilliana*, *A. spondylophylla* and *Mirbelia viminalis*. Reports have been written to summarise the results and provide provenancing recommendations for all species. Chloroplast sequencing is currently underway.

- A paper on phylogeographic patterns and genetic diversity in *Grevillea paradoxa* and *Melaleuca nematophylla* is ready for peer review. 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 *G. globosa* has been published in *The Botanical Journal of the Linnean Society*. In *Mirbelia* 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.
- Comprehensive seed collection and restoration establishment guidelines for the four species from the Midwest region have been provided to Karara Mining Limited.

Management implications

- Pilbara seed collection zones—The high levels of genetic diversity and low levels of differentiation within *E. leucophloia* and *A. ancistrocarpa* imply that, for these species, seed resources for land rehabilitation and mine-site revegetation programs can be selected from a wide distributional range within the Pilbara. However, phylogeographic analysis of *E. leucophloia* has identified the Hamersley Range as a historical refugium, so seed collections for rehabilitation of mine sites using this species should be targeted within the Hamersley Range to maximise the diversity of these sites. In contrast, the low diversity and high population differentiation in *A. atkinsiana* indicates that more restricted seed collection zones should be observed.
- *Aluta quadrata*—The significant genetic structure in *A. quadrata* indicates three conservation or management units: Western Range, Pirraburdoo and Howie's Hole. Given the genetic differences, restricted distribution and size of the populations, a precautionary approach should be taken to seed collections. Establishment of restoration populations within gene flow distance of existing populations should be done with seed from the location of that population. However, mixing seed collections from the three locations for establishment of restoration sites located distant to existing populations would be a means of maximising genetic diversity for future conservation.
- *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

- Manuscripts currently in review will be finalised.

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

Wetlands Conservation

Program Leader: Adrian Pinder

The Wetlands Conservation Program undertakes research in a range of disciplines to support the management of wetlands in the State's conservation estate. 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, climate change 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.

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

SP 2015-017

Team

M Pennifold, A Pinder

Context

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

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

Aims

- 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 Parks and Wildlife managed wetlands and their response and vulnerability to threats.

Progress

- A journal article is being prepared on how landscape modelling of compositional turnover in aquatic invertebrates informs conservation,

- Conducted summer 2015 sampling of aquatic invertebrates in Muir-Byenup Ramsar wetlands.
- Processing of Muir-Byenup invertebrate samples largely completed.
- Identification and vouchering of Muir-Byenup invertebrates in progress.
- Collaborating with taxonomists to reconcile taxonomic issues between 1996/97, 2003/4 and 2014/15 data for the Muir-Byenup wetlands.

Management implications

- Re-surveying the Muir-Byenup Ramsar and other high value wetlands will provide the region with knowledge of how these wetlands and their fauna have responded to threats over the last 20 years. This, in conjunction with results from the peat wetlands project (SPP2014-24), will 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 addressing these commitments will inform future forest management practices.

Future directions

- Identify and voucher Muir-Byenup invertebrates collected in 2014/2015.
- Consolidate Muir-Byenup invertebrate data from 1996/97, 2003/04 and 2014/15 and produce a report.
- Publish report with summaries of 10 year trends (2005 to 2015) for all stream monitoring sites.
- Re-sample selected streams in 2016, with a focus on those considered to be in reference condition or in minimally disturbed catchments, plus those subject to wildfires, to provide long-term data on the response of aquatic invertebrate communities to declining rainfall and forest management.
- 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 prioritise these wetlands for the Warren Region Nature Conservation Plan.

South West Wetlands Monitoring Program (SWWMP)

SP 2015-002

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 105 wetlands, with data added to the South West Wetlands Monitoring Program (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.
- The 'Thirty Year (1981-2010) Trends' report was completed, presenting trends in water levels and rainfall at 113 south-western Australian wetlands monitored under SWWMP.
- A report on 'Water levels and rainfall of 14 south-western Australian wetlands: continuous recordings from 2009-2015' was prepared to final draft.
- Lake Jasper was salinity-profiled. While still fresh, Lake Jasper has become more saline over the past decade. Long-term monitoring is at a single point. Profiling was undertaken to provide a broader basis for future comparison and understanding.
- Work continued on a report analysing relationships between wetland character and aquatic fauna in 25 representative wetland sites monitored between 1996 and 2012.
- Curating and long-term archiving of the 1996 to 2012 aquatic invertebrate specimen collection was commenced.
- Data analysis for dominant overstorey trees commenced on Wheatbelt wetlands with the production of size class histograms to examine population structure and seedling recruitment over time.
- Groundwater data collection was undertaken in autumn 2016.

Management implications

- Rainfall 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.
- The SWWMP project provides early warnings of 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 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, increase water levels at Jandabup and Thomsons Lakes, manage salinity at Lake Toolibin, and manage depths for water skiing at Lake Towerinning.
- Analyses of the flora and fauna data from 25 representative wetlands will allow managers to predict future impacts of altered hydrology and assess management responses in similar wetlands and understand the trajectory of Wheatbelt wetland biodiversity more generally.

Future directions

- Complete write-up of the 15 years of fauna and flora monitoring at the 25 intensively monitored wetlands and archive data.
- Re-design and implement a focused Wheatbelt wetland ecological monitoring program to track changes in priority wetlands in relation to threats and management.

- By interpolation and modelling, fill gaps in the SWWMP water level time series to substantially increase the number of wetlands that can be included in decadal and multi-decadal trend analyses.
- Prepare a 1981-2015 update of the thirty year (1981-2010) trends report on water levels and rainfall of the more than 100 south-west wetlands of SWWMP.
- Complete the 2009-2015 continuous water level and rainfall recordings report.
- Use results of long-term periodic water level, salinity and ph monitoring, continuous on-site rainfall and water level monitoring, and other datasets, to predict likely futures of wetlands important for Australasian bittern and other fauna and flora in different climate scenarios.

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

SP 2015-001

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).
- To produce risk assessment framework(s) to prioritise conservation actions and assess the transferability of research outcomes.

Progress

- Uploaded over 200 hydrological datasets to the Parks and Wildlife Data Catalogue.
- Collected borehole geophysical data at Lake Bryde to assign aquifers to key bores and report on the spatial distribution of sediments as well as the quality of groundwater and soil water.
- Produced scientific reports detailing the achievements of the last 20+ years of hydrological investigations and monitoring.
- Developed rationalised, long-term hydrological monitoring programs for key wetland assets.
- Facilitated handover of the hydrological data collection and management to the Wheatbelt Region.
- At Toolibin Lake interpreted quality assured data to construct a quantitative conceptual hydrogeological model that is being tested numerically to assess the effectiveness of on-ground management actions.

Management implications

- Hydrological models will provide a sound hydrogeological understanding of the threats to high conservation value assets associated within the conservation estate in catchments of interest to the Department.
- New hydrological informing tools will be available to managers to inform decisions about effective management of ephemeral wetlands, including maintaining, replacing or redesigning existing hydrology engineering infrastructure, and species selection for re-vegetation programs.
- Archiving of Natural Diversity Recovery Catchment data in the Parks and Wildlife Data Catalogue will ensure that maximum value can be made of this high value resource into the future.

Future directions

- Develop a spatio-temporal conceptual model of deep-rooted vegetation resilience on Toolibin Lake and assess hydrological critical criteria that influence the success and decline of different plant species.
- Construct a solute transport numerical model to simulate changes in soil and aquifer water quality and examine results against quantitative conceptual models of changing soil condition and vegetation species resilience (Toolibin Lake).
- Complete remaining five reports and prepare a Science Information Sheet.

Taxonomy, zoogeography and conservation status of aquatic invertebrates

SP 2014-025

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

- To undertake aquatic invertebrate systematics to improve descriptions of Western Australian aquatic invertebrate biodiversity and allow more consistent identification of specimens by departmental and external researchers.

Progress

- A paper describing a new species of *Boeckella* copepod from a claypan on Matuwa (ex Lorna Glen) is nearing completion.
- A book chapter on Australian and New Zealand aquatic oligochaetes was commenced.
- Genetic barcoding of selected invertebrates was undertaken for a survey of claypans in the Fortescue Valley to enable larvae to be more consistently identified.

Management implications

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

Future directions

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

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

SP 2014-024

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, particularly water and chemical conditions and gradients.
- To map and quantify peat wetland carbon and acid stores.
- To identify and assess the transient behaviour of major threats to the health of the peat wetlands particularly the role of drying climate in changing water retention in peat sediments and the source and mobility of acidity and salinity.

Progress

- High resolution groundwater monitoring on shorelines of three wetland types showed that resilience was higher where wetlands were discrete in size, rainfall-runoff response was high and aquifers beneath the wetlands were less dependent on local recharge to maintain high (near surface) water levels.
- All wetlands studied had high carbon and acid stores, which were released during sequential wetting and drying of lake sediments, in both summer and winter months.
- Laboratory analyses of peat sediments confirmed they have sufficient buffering capacity to neutralise acidity, but acidity prevailed where changes in surface and groundwater hydrology resulted in lower water retention in the peat sediments.

Management implications

- It is likely that small changes in water balance make a significant difference to peat wetland health. An understanding of these changes will enable informed management of surrounding vegetation to reduce impacts on water balance and consequently improve peat wetland health.
- Analysis of peat wetlands show that stores of organic carbon are significant to depths of ~1.5m and persist as wetland substrates dry. Understanding the spatial variability of these carbon stores and the rate of decline will assist in predicting fire risk.

Future directions

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

Western Australian wetland fauna surveys

SP 2011-018

Team

A Pinder, K Quinlan, R Coppen, L Lewis

Context

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

Aims

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

- Completed a brief report on aquatic invertebrates from the Brixton Street Threatened Ecological Community (TEC) wetland for Swan Region.
- Published a paper on aquatic invertebrates of Goldfields wetlands sampled in 2014 following a rare summer rainfall event.
- Published paper on aquatic invertebrates of Cervantes to Coolimba area wetlands as part of an offset provided by CSR Gyprock.
- Re-scored fringing flora quadrats of wetlands in the Cervantes to Coolimba area and commenced work on a paper.

- Surveyed aquatic biodiversity of the springs and wetlands around Mandora Marsh (Walyarta) in spring 2015 and identified ~85% of specimens.
- Continued to survey aquatic invertebrates and flora from wetlands in the middle to upper Fortescue Valley as part of a Pilbara Corridors - Rangelands NRM project. Work included identifying 95% of the invertebrate specimens and all of the flora specimens collected from wetlands on Mulga Downs station in 2014/15, surveying wetlands on Ethel Creek and Roy Hill stations and commencing identification of the resulting flora collection.

Management implications

- In the Cervantes to Coolimba wetland system, the survey of wetland flora will assist with assessment of proposals to expand gypsum mining and determining the ecological water requirements of groundwater dependent ecosystems.
- 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 assessment and approvals decision making.
- On the Swan Coastal Plain the analysis of data collected from a TEC fills a data gap (aquatic invertebrates in seasonal vegetated claypans) that will allow more informed land use planning.
- Information from the 2015 survey work on Mandora Marsh (Walyarta), combined with the baselining work completed there in 1999, will enable more informed conservation planning for the new Walyarta Conservation Park, including assessment of management actions taken to protect mound springs. Survey results will also be used to report on the ecological character of the springs when reporting on this Ramsar wetland to the Commonwealth.
- In the Fortescue Valley, surveys of wetland biota will inform efficient wetland conservation planning in an important area for wetland biodiversity in the Pilbara.

Future directions

- Publish paper on invertebrate diversity in vegetated claypans of south-west Western Australia.
- Publish meta-analyses of Western Australia arid zone invertebrate surveys.
- Complete paper on Cervantes to Coolimba area wetland flora.
- Complete identifications and supplementary molecular work for Mandora Marsh (Walyarta), analyse data and provide a report to the Kimberley Region.
- Complete identifications of already collected flora and fauna from the Pilbara Corridors project, survey additional wetlands on Roy Hill and Mount Florence stations and analyse data.

Marine Science

Program Leader: Alan Kendrick

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

Long-term monitoring in the proposed Dampier Archipelago marine reserves

SP 2015-015

Team

M Mohring, A Kendrick, S Wilson

Context

The Pluto LNG Project Offset D program includes the requirement to establish long-term monitoring reference sites in the proposed Dampier Archipelago Marine Park and Regnard Marine Management Area in accordance with the State Government's indicative management plan for the area. This task will require a prioritisation of ecological assets, the establishment of long-term monitoring sites to assess spatial and temporal distribution of key assets, and the provision of quantitative evidence on the status of these assets. This work will also help develop best practice monitoring techniques for assets and pressures where knowledge is lacking, and provide valuable information to Parks and Wildlife's marine planning and conservation initiatives.

Aims

Develop and implement a monitoring, evaluation and reporting program of key biodiversity asset condition and their major pressures at key sites in the proposed Dampier Archipelago Marine Park and Regnard Marine Management Area.

Progress

- A monitoring prioritisation assessment for the study area was completed.
- Permanent survey sites were established and the first surveys of coral communities and fishes were completed.
- Collaborative fieldwork was undertaken with CSIRO to measure coral recruitment at long-term monitoring sites.
- Historical satellite imagery was purchased to develop time-series data on mangrove communities in the study area.
- A *Landscape* article on this study was published.

Management implications

- This project will produce baseline data on various key ecological assets and the pressures acting on them, as well as several recurrent surveys to detect trends in key asset condition. An established monitoring program will inform Parks and Wildlife managers of trends in asset condition to facilitate long-term adaptive management for the proposed reserves, and promote environmental understanding for a range of stakeholders and the community.
- New marine monitoring indicators and methods for key ecological assets and habitats that are largely novel to northern Western Australia, will provide a sound basis for management of the proposed Dampier Archipelago Marine Park and Regnard Marine Management Area.

Future directions

- Establish monitoring sites for mangrove communities, undertake remote and in-situ monitoring surveys, and ground truth the findings of remote imagery analysis.
- Establish monitoring sites of seagrass and macroalgae, including the trial of multiple techniques to determine a best practice, Standard Operating Procedure to be implemented across Western Australia's tropical marine parks and reserves.
- Undertake a second monitoring survey of coral and finfish communities at sites established in 2015.

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

SP 2014-021

Team

K Waples, H Raudino, R Douglas, C Severin

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 expansion of the resources sector, including oil and gas exploration and production, coastal infrastructure development and shipping. While this is a key factor that proponents are required to address to secure State and Commonwealth environmental approvals, impact assessments for these species are complicated by the lack of best practice protocols and standards for survey design and data collection, which limits the comparison of different studies and study sites. This project will provide a better understanding of these species and their spatial and temporal use of Pilbara coastal waters and lead to greater certainty in assessing and managing impacts that relate to industrial developments. This project was designed to meet this priority need under the Wheatstone Offset C program.

Aims

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

Progress

- Conducted two boat-based dolphin surveys (autumn and winter) around Onslow. These data will be used to estimate the density and abundance of coastal dolphins in the area if the encounter and re-sighting rate is sufficient.
- Conducted an aerial survey of coastal waters from Exmouth Gulf to Port Hedland and extending offshore to the 20 metre depth contour, including the Montebello Islands. Data collected from this survey will be used to produce an estimate of dolphin density for the surveyed area.

Management implications

- This research will provide a baseline understanding of dolphin habitat usage of the Pilbara region, which will inform the assessment of environmental impacts relating to future coastal developments, and will assist to determine the conservation status of coastal dolphin species in Pilbara waters.
- The research will establish baseline data and long-term monitoring protocols for coastal dolphin species in State waters.

Future directions

- The established vessel survey methodology and design will continue for a third year and additional survey sites may be added in the Dampier Archipelago area.
- The aerial survey design will be reviewed based on recent results and adjusted as needed for the third aerial survey in 2016/17.
- Existing data will be analysed to produce abundance estimates for at least two dolphin species (bottlenose and humpback dolphins) across the study area.
- Survey data will be collated with other datasets to produce spatial habitat models of dolphin presence and relationships with key environmental factors across the Pilbara region.

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

SP 2014-018

Team

K Waples, H Raudino

Context

The current lack of knowledge of the Australian snubfin dolphin (*Orcaella heinsohni*) meant that its conservation status could not be properly assessed in 2011 due to 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 Western Australia, there has been little Western Australian-based research on this species and much of this remains unpublished. This project will compile existing data on snubfin dolphins across the Kimberley to gain a better understanding of their habitat use and distribution. The collation of data into a single database will also facilitate the study of population structure and demographics based on recognised individual animals. This project will assess dolphin distribution across the Kimberley region between 2004-2012.

Aims

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

Progress

- A manuscript on cross-cultural knowledge of the distribution of snubfin dolphins in the Kimberley has been prepared.
- A manuscript on snubfin dolphin abundance contrasting distance sampling and mark-recapture survey techniques in Roebuck Bay has been prepared for submission.

Management implications

- Collation of scientific and traditional knowledge of a poorly understood marine mammal species of high conservation value means managers now have baseline knowledge of the abundance of snubfin dolphins in the proposed Yawuru Nagulagun / Roebuck Bay Marine Park.
- Establishment of a database for all dolphin research and monitoring where survey and photo-identification data is collected to ensure that standardised data is available for assessing population abundance and distribution. It also provides the capacity to develop sighting histories for individual animals, thus providing a better understanding of population demographics and life history. This database can also be used for information sharing across jurisdictions and between research organisations.
- The broad-scale collation of information and modeling has provided relevant information on area of occupancy and extent of occurrence that can be used to more accurately assess the conservation status of snubfin dolphins.
- Partnerships have been established with indigenous sea ranger groups to develop survey methodologies, data storage and reporting structures that are consistent with healthy country plans and reserve management plans.

Future directions

- Submission of a manuscript on a population estimate of the Australian snubfin dolphin in Roebuck Bay to a peer-reviewed journal.
- Submission of a manuscript on cross-cultural knowledge of the distribution of the Australian snubfin dolphin to the journal *Biological Conservation*.

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

SP 2014-005

Team

G Shedrawi, A Kendrick, M Rule

Context

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

Aims

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

Progress

- Installed cameras and a web-based application that enabled Parks and Wildlife staff to view near real-time video footage of people crossing the sandbar spit between Mersey Point and Penguin Island. This system includes the automated conversion, upload and corporate storage of video footage of both little penguin beach arrivals and visitor sandbar crossings.
- Data collected during 2014-15 were analysed to determine the proportion of Penguin Island visitors using the sandbar as an access route instead of the ferry service. This identified peak periods and environmental conditions when visitors used the sandbar as an access point to Penguin Island.
- Data and preliminary findings collected during 2014-15 were summarised and presented to Swan Coastal District and the Coroner's working group.
- A Department-hosted web application was implemented that enabled staff and community volunteers to analyse infrared recordings of little penguin beach arrivals.

Management implications

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

Future directions

- Compile a final report on visitor use of the Penguin Island sandbar.
- Improve the utility of camera systems as a monitoring tool by increasing the resolution of imagery.
- Investigate further options to promote community engagement with little penguin monitoring.
- Integrate this technology and methods into the Department's long-term marine monitoring program for little penguins.

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

SP 2014-004

Team

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

Context

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

Aims

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

Progress

- Coral recruitment settlement tiles were deployed and collected in the Onslow region for the third year of the temporal study of recruitment processes.
- A third in-situ assessment of recruit corals on Onslow region reefs was undertaken using quadrats with underwater visual census and digital photographs.
- Pre-dredging benthic images provided by Chevron were analysed to understand the size-class frequency distribution of corals in the Onslow region.
- DNA extractions, sequencing and data analysis for mangroves, seagrass and fish were completed.
- Coral extractions are still in progress with some delays caused by taxonomic and technical issues.
- One paper on techniques to identify cryptic species of coral is in press with *Coral Reefs*.
- A paper on coral population genomics and connectivity is in review with *Global Change Biology* and a review of dredging impacts on fishes has been submitted to *Fish and Fisheries Review*.
- A *Landscape* article titled *Understanding Marine Connectivity* is in press.

Management implications

- The project will improve our understanding of how well populations of marine species are linked, providing an indication on how fast they are likely to recover following natural and anthropogenic disturbances, with a focus on key habitat forming species that support important ecological processes.
- Understanding the extent of connectivity for different taxa will inform marine planners about how reserves and management zones can be configured to best facilitate propagule transfer among meta populations, therefore improving recovery potential after disturbance.

- Improved temporal understanding of the impact of natural and human disturbance in the Pilbara, as well as the demography and recovery potential of coral communities, will allow resource managers and industry to understand the resilience of the system, and allow for better spatial and temporal planning of developments and general use management zoning.

Future directions

- Laboratory work will continue for the coral connectivity study, including DNA extracting and sequencing, data analyses and manuscript preparation.
- Analyses of genetic data for fish, mangroves and seagrass species will be completed and manuscripts for all genetic results will be prepared.
- The third year of data on coral settlement will be analysed and coral settlement tiles will be re-deployed in February and May 2017 to determine settlement differentials across the period of spawning.
- Analysis of benthic images from 'post dredge operations' period for coral demographics assessment and reporting.
- Analysis and preparation of a manuscript on coral recovery potential in the Onslow region.

The influence of macroalgal fields on coral reef fish

SP 2013-006

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 the influence of juvenile fish on replenishment and future adult abundance.

Progress

- A paper documenting the movement of fish to macroalgal patches with greater cover and canopy height in response to seasonal shifts in macroalgal assemblages has been published in the journal *Ecosphere*.

- Work on seasonal fluxes in macroalgal biomass and the importance of tropical macroalgae as habitat for fish has been presented as seminars at the University of Stockholm, Sweden, The University of Singapore and to Parks and Wildlife staff in the Exmouth District. It has also been incorporated into two posts on Departmental social media.
- Field data for four summers and three winters has now been collected.
- Data collected from this project has been incorporated into a wider geographic analysis of shifts in macroalgal communities along the Western Australian coast, which has now been accepted for publication in the journal *Science*.

Management implications

- Marine conservation managers and planners will have a greater understanding of the ecological and social importance of macroalgal habitats in Western Australia's tropical north. This includes the ecological importance of macroalgal fields as habitat for fishes and their role in supporting key processes such as recruitment. This knowledge will also improve the capacity to predict future abundances of adult fishes, particularly those threatened by changes to habitat, climate and fishing pressure, and will help to maintain important social values like recreational fishing.
- An improved understanding of the distribution of macroalgal fields in tropical Western Australia will improve predictions of the ecological significance of algal biomass when planning and managing marine reserves.
- This study of macroalgal communities will provide baseline data for future long-term monitoring of the condition of macroalgal communities in marine reserves.

Future directions

- Compile and analyse data to understand links between juvenile and adult fish, and assess the relative importance of juvenile abundance and suitable habitat.

Understanding movements and identifying important habitats of sea turtles in Western Australia

SP 2013-002

Team

S Whiting

Context

This project uses satellite telemetry to track turtles that are released to the wild with minimal and extensive rehabilitation. In addition, turtles are tracked to identify connectivity between different habitats in their life stages. Commonly turtles are tracked from nesting beaches to identify interesting habitat, migration routes and resident foraging grounds. The tracking results identify the geographic range and preferred habitats and provide insight into the viability and survivorship of healthy and rehabilitated turtles in the wild. The identification of preferred habitat allows pressures to be identified and prioritised for different size classes. As tracking results will be broadcast live on the internet (updated daily via seaturtle.org) there is a direct link between Parks and Wildlife science activities and the community. The genetic information (derived from samples collected routinely across a range of projects) will provide another layer of information that helps to describe the spatial range of turtles Western Australia

Aims

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

Progress

- Flatback turtles were tracked from four Western Australia nesting locations providing data on migration routes and the locations of inter-nesting habitats and foraging grounds.
- Loggerhead turtles were tracked from two sites. One loggerhead turtle travelled from its nesting beach at the Muiron Islands in Western Australia to the Torres Strait, a distance of 3400 km.
- Hawksbill turtles were tracked from one site.
- One rehabilitated olive ridley turtle was tracked after 20 weeks in care.
- Tracking data from all the turtles can be viewed at www.seaturtle.org.

Management implications

- Understanding spatial use by turtles is essential for management. The current studies have collected data that will enable calculations of time spent inside and outside marine reserves, the identification of high use migration corridors and the locations of important foraging areas and interesting habitats.
- This study has already identified new key habitats used by the Northwest Shelf flatback turtle stock. These habitats include foraging areas in the southern Pilbara, inshore inter-nesting areas near Onslow and the confirmation of foraging areas in the north Kimberley.
- The movement of loggerhead turtles from Western Australia to the Northern Territory and Queensland has cross jurisdictional implications for the broadscale management of this migratory species and highlights the need for collaboration with other States and Territories.

Future directions

- Continue to track turtles to understand the spatial context of habitat use and determine if there are areas that overlap extensively with human pressures.

The Western Australian Marine Monitoring Program (WAMMP)

SP 2012-008

Team

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

Context

A state-wide system of marine protected areas is being established in Western Australia as part of Australia's National Representative System of Marine Protected Areas. Long-term monitoring of the condition of environmental assets and social values is recognised as an integral aspect of adaptive management. The Department's marine monitoring program is a state-wide, long-term, marine monitoring, evaluation and reporting program that

is being developed and implemented to increase the efficiency and effectiveness of marine reserve and threatened marine fauna conservation and management.

Aims

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

Progress

- A review was initiated into the scope and operations of the marine monitoring program to ensure that it is being conducted in an efficient manner, and in line with changes to reporting structures and operational capacity.
- Monitoring was undertaken for numerous biophysical assets (e.g. finfish, coral, seagrass, macroalgae, mangrove, penguins, turtles, little penguin, water quality, human use) across twelve marine reserves from Walpole Nornalup Inlets Marine Park in the south to Lalang-garram / Camden Sound Marine Park in the north.
- Monitoring reports were provided to Marine Park Coordinators on the condition of biodiversity assets and the significance of pressures acting on them in 12 marine parks and reserves to inform adaptive management strategies and Departmental reporting processes.
- Marine monitoring datasets were integrated into the Divisional CKAN data catalogue.
- Training on monitoring protocols for ecological assets such as coral, fish, seagrass, mangroves and little penguins was provided to Departmental staff, interns and volunteers.
- A paper on the distribution, abundance, diversity and habitat associations of fishes across a bioregion experiencing rapid coastal development was published in *Estuarine, Coastal and Shelf Science*.

Management implications

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

Future directions

- Finalise and publish supporting documentation that describes the the aims and structure of the marine monitoring program, including rationale for the selection of monitoring indicators and methods for key ecological assets.
- Continue the design and implementation of ecological asset monitoring across the marine reserve system, including at new and proposed reserves at Ngari Capes Marine Park and in Western Australia's Kimberley region.
- Continue to provide marine park managers with evidence-based knowledge of the condition of key ecological assets and the pressures acting on them to inform and assist the delivery of adaptive management.
- Continue to provide the scientific knowledge required for the Department's marine parks and reserves reporting process.

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

SP 2012-007

Team

M Mohring, C Nutt, A Kendrick

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

- The final report for this project was completed.
- Information collected during this study has been used to plan other projects in Pluto Offset D.

Management implications

- Understanding the effectiveness of current and past management relies on the 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. This project has ensured that historical marine datasets collected in the Dampier Archipelago area are now documented and available to assist conservation management of the proposed marine reserves.

Future directions

- Finalisation of the report means that this project has now been completed and will be closed.

North West Shelf Flatback Turtle Conservation Program strategic plan

CF 2011-118

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 program is to increase the conservation and protection of the Northwest Shelf flatback turtle population through: surveying, monitoring and research; reducing interference to key breeding and feeding locations; and establishing information and education programs. The Marine Science Program coordinates the planning and implementation of works required for the NWSFTCP in addition to coordinating general research and monitoring of marine turtles in Western Australia. The NWSFTCP has a range of governance arrangements that include an Advisory Committee and a 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.

Progress

- Draft management plan completed
- Several PhD student projects have commenced on the thermal biology of flatbacks, light impacts on flatbacks, turtle health and disease, and fox impacts on flatbacks turtles.
- Preliminary data collected on fox impacts on clutches of eggs at Mundabullangana Station.
- Nesting sites were mapped across the Kimberley as part of the WAMSI Turtle project turtle.
- Transmitters attached to over 20 flatback turtles.
- Published proceedings of the 2nd Australian and 2nd Western Australia Symposia.
- Draft Strategic Communications Plan developed.

Management implications

- The NWSFTCP Strategic Plan will map out the foundations of the program that establish a robust program of works within a strategic long-term framework. The NWSFTCP 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

- Investigate potential for in-water studies of flatback turtles, and critical habitat identification.
- Develop long-term monitoring plan, information management plan and finalise communications plan.
- 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.
- Finalised and published strategic plan.

WAMSI 2: Kimberley Marine Research Program

CF 2011-117

Team

K Waples, S Field

Context

The Kimberley Marine Research Program (KMRP) is undertaking a program of marine research to support the management of the proposed Great Kimberley Marine Park (which will include state marine parks at Camden Sound, Horizontal Falls, North Kimberley, Roebuck Bay and Eighty Mile Beach) and the coastal waters outside of these proposed marine parks. The KMRP is being 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 working collaboratively on 25 research projects. Aboriginal involvement is a key component to the success of the research program and all projects are engaging with Aboriginal people and developing partnerships with the relevant traditional owners to include their participation and to ensure the research outcomes benefit local communities.

Aims

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

Progress

- Field research has been completed for thirteen of the 21 projects while the remaining eight will be conducting field work in 2016/17. Thirteen of these 21 projects have included participation by traditional owners in field work.
- Final reports have been received and reviewed for three projects and milestone reports received, reviewed and approved for an additional 13 projects.
- The final Project Agreement for the Indigenous Knowledge project was completed and approved and the project work has commenced. This project includes a Saltwater Country Working Group with representatives from seven indigenous communities, all participating in this project on integrating indigenous knowledge with western science for healthy country management.
- Engagement with relevant traditional owner groups is ongoing and formal research agreements are in place with three indigenous groups. Relationships have been established and fostered with the Indigenous Protected Area 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.
- Two Science Review sessions have been held, evaluating eight KMRP projects. All actions arising from these reviews have been addressed.

- The Communication Strategy is being implemented through a range of activities, including media engagement, online project profiles and presentations.

Management implications

- The KMRP outputs will increase the capacity to manage human impacts in the Kimberley marine reserves and improve understanding of the ecological and socio-cultural significance of the biodiversity assets of the Kimberley for joint managers, industry and the community. The program also enhances the capacity of indigenous rangers and working relationships with indigenous communities, thereby increasing the opportunity for more productive and bipartisan joint management in the future. Findings are being used in the development of a monitoring program for key biodiversity assets across the Kimberley.

Future directions

- Review final reports and develop management implications and tools jointly with lead scientists and managers.
- Ensure that key research findings are shared with stakeholders in a format that allows for direct discussion and feedback on management needs, including products and tools that will support ongoing collaboration and management.
- Develop a synthesis of knowledge to provide a regional perspective on marine biodiversity, ecosystem function and the pressures on these values which can be mitigated by management.

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

SP 2010-008

Team

S Field, R Evans, G Shedrawi

Context

The Gorgon Project (GP), which is based on Barrow Island, is one of the world's largest natural gas projects and the largest single-resource natural gas project in Australia's history. The plant 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 final Gorgon dredging program report, which describes potential impacts of marine construction on bio-physical assets. All chapters are being finalised for submission.
- A paper on the examination of the utility of identifying coral disease from digital images has been submitted to *Environmental Monitoring and Assessment*.

Management implications

- Phase One of the Gorgon MER project provides Department managers and scientists with a relatively intensive baseline for assessing potential impacts on, and recovery of, coral communities within the MBIMPA, with a particular focus on potential impacts related to the dredging program for the Gorgon Project. Information outputs include temporal condition and related pressure measures for biophysical assets (e.g. coral, finfish and macro-invertebrate communities) that aligns with the Department's marine monitoring program for the MBIMPA.
- The data generated from this monitoring program 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.
- Incorporation of Gorgon MER Phase Two monitoring into the WA Marine Monitoring Program.
- Completion of peer reviewed publications and archiving of all data collected with WA Marine Monitoring Program.

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

SP 2009-013

Team

M Rule, A Kendrick

Context

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

Aims

- Determine spatial patterns in the WNIMP benthic invertebrate community.
- Determine temporal variation in the WNIMP benthic invertebrate community, particularly in relation to seasonal changes in the hydrological cycle of the inlet system.
- Assist to develop methods for long-term monitoring of benthic invertebrates in the WNIMP and more broadly across temperate estuarine marine protected areas.

Progress

- A collaborative Parks and Wildlife / Edith Cowan University (ECU) student camp was held at WNIMP in April 2016, with Coastal and Marine Management course students undertaking a study of bivalve community structure and recruitment in the estuary. Data were collected over four days and provided to Parks and Wildlife to assist future research planning. This was the third year of data collection for this project.
- Data (species identifications, abundances and shell lengths) collected by ECU students have been verified by Marine Science Program and entered into a database.
- Analysis of spatial and temporal benthic invertebrate community data is continuing.

Management implications

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

Future directions

- Detailed analyses of the spatial and temporal invertebrate dataset will be undertaken and used to develop a long-term monitoring program for benthic invertebrates in WNIMP.
- Additional ecological papers will be prepared.

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

SP 2009-003

Team

S Wilson, T Holmes

Context

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

Two critical processes that determine the community structure of coral reef fish are recruitment and early post-settlement predation. It is hypothesised that the degradation of coral-associated habitat due to climate change will cause a decline in recruit numbers. Conversely, fishing will reduce abundance of large predators and increase numbers of smaller habitat-associated predators, thereby increasing post-settlement predation.

Examining how changes in habitat and predators interact and influence post-settlement survival of fish will be critical to understanding the impacts on biodiversity of fish communities and fish populations.

Aims

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

Progress

- A paper reviewing recent research on the effects of climate change on fish and corals has been published in the journal *Diversity*.
- A paper identifying *Pocillopora* corals as important habitat for predatory hawkfishes has been published in the journal *PloS One*.
- A manuscript linking the extent of coral habitat at the time of juvenile recruitment with the abundance of adult fish has been submitted for publication in the journal *Proceedings of the Royal Society B*.

Management implications

- Environmental disturbances associated with climate change pose a major threat to the long term conservation of coral reefs in Western Australia's marine parks and reserves. Understanding which environmental factors promote recovery on coral reefs allows managers to identify which reefs are more likely to persist over time.
- This research project has identified two metrics, depth and structural complexity, that 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 reserves.

Future directions

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

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

SP 2009-002

Team

M Rule, A Kendrick, 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 Western Australia's south-west. These marine parks support a diverse range of marine conservation values ranging from various marine habitats to threatened marine fauna, and are dominated by sub-tidal and emergent limestone reefs and shallow sandy embayments. The marine parks are subject to high levels of recreational and commercial human

activity due to their proximity to population centres. Significant areas of intertidal reef platform occur in both mainland and island shores and as isolated offshore patch reefs. While a number of local studies of intertidal communities provide a significant regional knowledge base, the broad spatial patterns of intertidal biodiversity across MMP, SIMP and NCMP are not adequately understood. Particular gaps exist in our knowledge of the intertidal communities of offshore platform reefs. This study will determine spatial and temporal patterns in the distribution of intertidal reef organisms in Western Australia's temperate marine reserves. Relationships between the composition of these communities and the physical structure and location of the reefs will also be examined.

Aims

- Determine the spatial and temporal patterns in the composition of intertidal reef communities in the MMP, SIMP and NCMP, including the proposed northern extension to the SIMP.
- Determine if the intertidal reef communities in management zones protected from extractive activities differ from the intertidal reef communities of otherwise comparable reefs.
- Assist in the development of methods for long-term monitoring of intertidal communities in temperate marine reserves.

Progress

- A manuscript describing differences in community structure on intertidal granite and limestone substrates at NCNP was initiated.
- Preliminary intertidal surveys were commenced at six new sites at Jurien Bay Marine Park in conjunction with regional staff. A total of 37 species were recorded during these surveys, 13 of which had not been recorded in previous surveys of temperate marine reserves.

Management implications

- As the first comprehensive spatial and temporal study of the biological communities associated with intertidal reefs of Western Australia's temperate marine parks and reserves, this work provides a baseline understanding of intertidal reef condition in the marine reserves in relation to natural processes and possible anthropogenic impacts. The results will assist to ascertain the conservation significance of these habitats and assist the implementation of long-term intertidal reef monitoring and management in marine parks and reserves.

Future directions

- Ecological papers from data collected in MMP, SIMP and NCMP will be published.
- A species identification guide to assist future intertidal reef monitoring in MMP and SIMP will be completed.
- Intertidal reef surveys at NCMP will continue.
- A pilot survey examining broad-scale, latitudinal patterns in diversity will be conducted in the MMP and SIMP during the summer of 2016/17

Ecoinformatics

Program Leader: Paul Gioia

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

Provision of authoritative names of Western Australian taxa

CF 2011-108

Team

P Gioia

Context

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

Aims

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

Progress

- WACensus re-architecture has commenced, making data more easily available to other applications and systems requiring authoritative taxon name information.
- Smut names were added to WACensus.
- Minor bugs have been fixed and enhancements implemented as required.

Management implications

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

Future directions

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

Online GIS biodiversity mapping (*NatureMap*)

CF 2011-106

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

- In 2015 Australian conservation agencies and the Atlas of Living Australia (ALA) agreed to make species occurrence data held by the ALA available to the State that species occurrences are located in, from all providers and at original spatial resolution. This means more fit-for-purpose data is available for conservation planning and environmental impact assessment. *NatureMap* now provides the most comprehensive and accurate repository available for Western Australian species occurrence data.
- A range of new datasets were added, including BushBlitz and various community surveys, and new reference layers.
- Occurrence records now total 4.2 million, an increase of over 800,000 records (24%).
- The number of datasets warehoused has increased from 61 to 69 (13%).
- *NatureMap* recorded 200 new registrations over the last twelve months, bringing the total from 1953 to 2153, a 10% increase.

Management implications

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

Future directions

- Continue incorporation of new and historical survey data into *NatureMap*, including Pilbara Islands historical surveys, Pilbara region biological survey and Kimberley Islands biological survey.
- Integration with the new proof-of-concept BioSys (biological survey) database.
- Implementation of a new Rangelands theme.

External Partnerships

Partners	Project Title	External Funding	Parks and Wildlife Involvement
ANSTO radionuclides	Investigation of radionuclide contamination at Montebello Islands to understand implications for turtles and researchers	\$20,000	S Whiting
ARC Linkage Charles Darwin University, University of Melbourne	Arresting declines of arboreal mammals in the tropical savannas	\$327,000 (2015-2019)	I Radford
ARC Linkage, Australian National University, CSIRO, Alcoa	Genomics for climate adaptation in <i>Eucalyptus</i> foundation species	\$375,000 (2013-2016)	M Byrne
ARC Linkage, Australian National University, Western Australian Museum, South Australian Museum	Phylogenomic assessment of conservation priorities in two biodiversity hotspots: the Pilbara and the Kimberley	\$570,000 (2012-2015)	M Byrne, D Coates, K Thiele
ARC Linkage, Karara Mining Ltd, The University of Western Australia	Managing genetic diversity and evolutionary processes in foundation species for landscape restoration in the midwest of Western Australia	\$527,000 over three years	D Coates, M Byrne, M Millar
ARC Linkage, Murdoch University - School of Veterinary and Life Sciences	The ecology of parasite transmission	\$150,000 over three years	A Wayne, K Morris
ARC Linkage, The University of Western Australia, Botanic Garden and Parks Authority	Is restoration working? An ecological assessment	\$520,000	D Coates, M Byrne, MA Millar
ARC Linkage, The University of Western Australia, Chevron, Rio Tinto, Botanic Parks and Gardens Authority	Defining biologically significant units in spinifex (<i>Triodia</i> spp.) for improved ecological restoration in arid Australia	\$549,000 over four years	K Thiele, S van Leeuwen
ARC Linkage, University of Sydney, Department of the Environment, Australian Reptile Park	Predicting the ecological impact of cane toads on native fauna of north western Australia	\$503,000 over three years	D Pearson
ARC Linkage, University of Tasmania, Department of Primary Industry - New South Wales, Department of Environment, Water and Natural Resources - South Australia, Smithsonian Institute (USA).	Functional responses of rocky reef communities to effects of fishing and other anthropogenic stressors.	\$900,000	T Holmes
ARC Linkage, University of Western Sydney, Murdoch University	Drought-resilient genotypes for sustainable and productive forests	\$281.505	M Byrne, R Mazanec
Anglogold Ashanti, Department of the Environment, Rangelands NRM	Great Victoria Desert Biodiversity Trust: Bioregional plan and Sandhill dunnart survey guidelines	\$85,000	S van Leeuwen, L Gibson, M Williams, D Pearson, M Cowan

Partners	Project Title	External Funding	Parks and Wildlife Involvement
Atlas Iron, Fortescue Metals Group, Iron Ore Holdings, Roy Hill, Main Roads Western Australia	Ecology and management of the northern quoll in the Pilbara	\$240,000 (2015-2016)	K Morris, A Dunlop, K Rayner, S van Leeuwen
Atlas Iron, Roy Hill	Investigating the interactions between feral predators in the Pilbara	\$450,000	K Morris, S van Leeuwen
Atlas Iron	Ecology and management of the Pilbara leaf-nosed bat	\$450,000	S van Leeuwen, K Morris
Atlas of Living Australia, Council of Heads of Australasian Herbaria, CSIRO	Collections Community Developer and Botanical Collections Community Coordinator	\$80,000	J Huisman, R Butcher, K Thiele, B Richardson
Australian Biological Resources Study	Kiwirrkurra Bush Blitz	\$12,000	M Williams, M Cowan, R Butcher, R Davis
Australian Institute of Marine Science (AIMS), Australian National University	Coral reef fish recruitment study	Nil	S Wilson, T Holmes
Australian Institute of Marine Science (AIMS), CSIRO	Mapping flatback foraging areas in the Kimberley	\$1,000,000	Tucker, S Whiting
Australian Institute of Marine Science (AIMS), The University of Western Australia	Understanding the early offshore movement of flatback turtle hatchlings and the effects of anthropogenic light	\$400,000	S Whiting
Australian Institute of Marine Science	Potential anthropogenic impacts on Ningaloo whale sharks as determined through the tourism electronic monitoring system and scarring patterns.	Nil	H Raudino, K Waples
Australian Transect Network, CSIRO, Terrestrial Ecosystem Research Network, National Research Infrastructure for Australia	South-Western Australian Transitional Transect	\$12,000	S van Leeuwen, N Gibson, M Byrne
BHP Billiton, Main Roads Western Australia, Atlas Iron	Ecology and management of the Pilbara olive python	\$200,000	D Pearson, S van Leeuwen, K Morris
BHP Billiton	Biological survey of Walyarta	\$50,000	A Pinder, K Quinlan, A Markey
BHP Billiton	Identification botanist position at the Western Australian Herbarium	\$105,000	K Thiele, J Huisman
Biodiversity Fund, Warren Catchment Council, CSIRO	Restoring natural riparian vegetation systems previously infested by blackberry along the Warren and Donnelly Rivers	\$2,945,000 (2011-2017)	M Byrne
Bushfire and Natural Hazards CRC	Bushfire and Natural Hazards CRC	Nil	L McCaw
CSIRO Health and Biosecurity, Koolan Island Mining, National Environmental RScience Program -Northern Australia Environmental Hub	Invasive <i>Passiflora foetida</i> in the Kimberley and Pilbara: understanding the ecology, threat and exploring solutions	\$250,000	S van Leeuwen
CSIRO and independent scientists	Explaining and predicting the occurrence of night parrots (<i>Pezoporus occidentalis</i>) using GIS and ecological modelling	\$38,000	AH Burbidge

Partners	Project Title	External Funding	Parks and Wildlife Involvement
CSIRO, Australian SuperSite Network, Terrestrial Ecosystem Research Network, National Research Infrastructure for Australia	Great Western Woodlands SuperSite	Nil	S van Leeuwen
CSIRO, The University of Western Australia, National Marine Fisheries Service (USA), Northern Territory Museum, Western Australian Museum	Skeletochronology and Stable Isotope analyses of flatback turtles	\$400,000	Tucker, S Whiting
CSIRO, University of Tasmania, Edith Cowan University	Climate-resilient vegetation of multi-use landscapes: exploiting genetic variability in widespread species	\$298,000	M Byrne, C Yates, B Macdonald, R Binks, L McLean
CSIRO	Fire regimes and impacts in transitional woodlands and shrublands	Nil	C Yates, C Gosper
CSIRO	Pilbara Marine Conservation Program	Nil	T Holmes, K Waples, A Kendrick, G Shedrawi
CSR Gyprock	Wetland flora and fauna of the Jurien coast	\$70,000	K Quinlan, A Pinder, M Lyons, R Coppen
Caring for our Country	Identifying threats to marine biodiversity of the Ningaloo World Heritage Area: deeper water fish community surveys within the Ningaloo Marine Park	\$65,000	T Holmes
Central Desert Native Title Services, Bush Heritage	Biological survey of the Birrilburru Indigenous Protected Areas	\$25,000	S van Leeuwen, K Quinlan, M Langley, N Gibson, M Cowan, A Pinder, L Gibson
Charles Sturt University	Introduced predator interactions with an endangered native predator, the Pilbara northern quoll	\$85,000	J Dunlop
Chevron - Gorgon Net Conservation Benefit, James Cook University, ARC Centre of Excellence for Coral Reef Studies	Decision support system for prioritising and implementing biosecurity on Western Australia's islands	\$5,000,000 over five years	C Lohr, K Morris, L Gibson
Chevron - Net Conservation Benefit	Cat eradication on Dirk Hartog Island	\$3,000,000 (2012-2017)	D Algar, M Johnston, J Fletcher, N Hamilton, C Tiller, M Onus
Chevron	Translocations of mammals from Barrow Island: offset program	\$9,500,000 (2009-2019)	K Morris, N Thomas, C Sims, J Angus, S Garretson, M Blythman
Curtin University, The University of Western Australia, University of Saskatchewan	Protecting the safe havens: will granite outcrop environments serve as refuges for flora threatened by climate change?	Nil	C Yates, M Byrne, S Tapper
Department of Fisheries, CSIRO, Australian Institute of Marine Science, Curtin University	Connectivity of coral trout populations between individual reefs on the Rowley Shoals	Nil	AR Halford
Department of the Environment - Threatened Species Commissioner, Rangelands NRM	Development of Hisstory bait for feral cat control	\$250,000	D Algar, M Onus, N Hamilton, M Johnston

Partners	Project Title	External Funding	Parks and Wildlife Involvement
Department of the Environment, Scientec Pty Ltd	PAPP toxicosis and cat bait pellet development	Nil	D Algar
Department of the Environment	Western Australian black spot biological survey campaign	\$136,000	S van Leeuwen, L Gibson, M Cowan, N Gibson
Department of the Environment - Environmental Resources Information Network, Terrestrial Ecosystem Research Network	Essential Environmental Measures	Nil	S van Leeuwen, P Gioia
Environmental Consultants Association of Western Australia, Environmental Institute of Australia and New Zealand, Office of the Environmental Protection Authority	Best practice for fauna impact assessment	Nil	S van Leeuwen, AH Burbidge, M Cowan, K Morris, M Williams, N Thomas
Fortescue Metals Group, BHP Billiton	Floristic survey of the Fortescue Marsh	\$245,000 (2014-2016)	S van Leeuwen, M Lyons, A Markey
Fortescue Metals Group, Millennium Minerals, Roy Hill	Ecology and management of the bilby in the Pilbara	\$215,000 (2015-2016)	K Morris, S van Leeuwen, F Carpenter, M Dziminski
Fortescue Metals Group	Vegetation map reconciliation and compilation for the Hamersley and Fortescue subregions in the Pilbara	\$160,000 over three years	S van Leeuwen, B Bayliss
Fortescue Metals Group	Fortescue Marsh feral cat baiting project	\$700,000 over five years	D Algar, S van Leeuwen
Geocatch, Edith Cowan University, Department of Fisheries	The long-term monitoring of seagrass communities in Geographe Bay	\$10,000	M Rule
Greening Australia, Rangelands NRM, Pilbara Corridors	Pilbara Corridors - Conservation Action Plan for the Pilbara Bioregion	Nil	S van Leeuwen
James Cook University	Decision support system for prioritising and implementing biosecurity on Western Australia's islands	\$2,040,000 (2012-2017)	C Lohr, K Morris, L Gibson
Landgate	Western Australian State Government Data Catalogue	Nil	F Mayer
Main Roads Western Australia, Environs Kimberley, WWF, Kimberley Land Council, Rangelands NRM	Conservation and management of the bilby (<i>Macrotis lagotis</i>) on the Dampier Peninsula, Kimberley.	\$600,000 over three years	M Dziminski, F Carpenter, K Morris, S van Leeuwen
Millennium Seed Bank, Australian Seed Bank Partnership, Department of the Environment	Seed collection, storage and biology	\$12,000	A Cochrane, D Coates
Murdoch University - Centre for Fish, Fisheries and Aquatic Ecosystems Research, South West Catchments Council	Fish and invertebrates of the Vasse-Wonnerup Ramsar site	\$14,000	J Lane, A Clarke
Murdoch University, Curtin University	Evidence based management of foxes adjacent to turtle beaches in Western Australia	\$300,000	S Whiting
Murdoch University: Centre for Fish, Fisheries & Aquatic Ecosystems Research, Caring for our Country	Fish populations and invasive species of the Vasse-Wonnerup Ramsar site	\$215,000	J Lane, A Clarke

Partners	Project Title	External Funding	Parks and Wildlife Involvement
Murdoch University	The health status of marine turtles in northern and western Australia	\$200,000	S Whiting
Murdoch University	Genetic studies of Pilbara EPBC Act listed Threatened vertebrate fauna	\$235,000	K Morris, D Pearson, S van Leeuwen, M Cowan, J Dunlop
National Environmental Science Program - Threatened Species Recovery Hub	Project 4.3: Improving threatened plant reintroduction success and species recovery.	\$699,000	D Coates, L Monks, R Dillon, M Byrne
National Science Foundation (USA)	Systematics and Biogeography of the Inocybaceae	\$19,000	N Bougher
North Australian Marine Research Alliance	Assessing spatial and demographic structure of anthropogenic mortality on Australasian marine turtles	\$300,000 (2012-2014)	S Whiting
Parks Australia and other Christmas Island land management organisations	Christmas Island cat eradication	\$250,000 (2015-2020)	D Algar, N Hamilton
Pilbara Corridors, Rangeland NRM	Biological survey of Fortescue River catchment clay pans	\$350,000 over two years	A Pinder, M Lyons, K Quinlan
Quadrant Energy	Coral recruitment monitoring in Ningaloo Marine Park	\$12,000	G Shedrawi
Rangelands NRM, Kanyirninpa Jukurrpa, Aditya Birla Minerals, Newcrest, Cameco, Bamford Consulting,	Throssell Coordinating Group	Nil	S van Leeuwen, K Morris, M Dziminski
Rangelands NRM, Pilbara Corridors, Greening Australia	Fortescue Catchment Project - Biodiversity assets and landscape-scale management of the Fortescue River catchment	Nil	S van Leeuwen, K Morris
Rhodes College Tennessee, St John's University New York, USA	Phylogenetics and floral symmetry development of the core Goodeniaceae	Nil	K Shepherd
Rio Tinto, BHP Billiton	Seed collection zones for the Pilbara	\$400,000	M Byrne, S van Leeuwen, D Coates
Rio Tinto, Queensland Herbarium, Darwin Herbarium	Resolving the systematics and taxonomy of <i>Tephrosia</i> in Western Australia	Nil	R Butcher, S van Leeuwen, K Thiele
Rio Tinto	Introduced predator control and baiting program - Yarraloola	\$3,000,000 over five years	K Morris, R Palmer, M Cowan, N Thomas, J Angus, H Anderson, K Rayner, S Garretson
Rio Tinto	Fire-mulga study: post-burn monitoring and tussock grassland survey of the Hamersley Range	Nil	S van Leeuwen, N Guthrie
Rio Tinto	Identification botanist position at the Western Australian Herbarium	\$114,000	K Thiele, J Huisman
Roy Hill, Atlas Iron, CSIRO Health and Biosecurity, Pilbara Corridors, Rangelands NRM,	Strategic weed assessment of the Pilbara Bioregion	\$350,000	S van Leeuwen
Royal Botanic Gardens - Kew, University of Portsmouth (UK)	The <i>Styloidium</i> phylogeny and pollination project	Nil	J Wege

Partners	Project Title	External Funding	Parks and Wildlife Involvement
South Coast NRM, Caring for Our Country	Increasing native habitat through protection of EPBC species and ecological communities (dibbler recovery)	\$30,000 (2011-2013)	A Friend
State NRM	Fast track critically endangered flora recovery	\$1,600,000 (2013-2015)	D Coates
Terrestrial Ecosystem Research Network, CSIRO	Australian Transect Network - South West Australian Transitional Transect (SWATT)	\$12,000	S van Leeuwen, M Byrne
Terrestrial Ecosystem Research Network, Pilbara Corridors	AusPlots Rangelands Pilbara 2015 and Kimberley 2016 campaigns	\$120,000	S van Leeuwen, N Casson
Terrestrial Ecosystem Research Network	AEKOS: ecoinformatics facility and development of ecological databases and portals	Nil	P Gioia
The University of Western Australia, Australian Institute of Marine Science, CSIRO Marine and Atmospheric Research, Department of Fisheries, Western Australian Museum	Temporal and spatial variation in coral cover on Western Australian reefs	Nil	S Wilson, G Shedrawi, S Field
The University of Western Australia, Botanical Gardens and Parks Authority	Is restoration working? An ecological genetic assessment.	\$520,000 over three years	D Coates, M Byrne, M Millar
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 Adelaide, Uppsalla University, AGRF, National Research Council Italy	Understanding adaptation to improve conservation of Australian flora	\$605,188	M Byrne
University of Adelaide	Wetland biological survey and monitoring: rotifer and cladoceran identifications	Nil	A Pinder, K Quinlan, D Cale, M Penniford
University of Michigan - Department of Ecology and Evolutionary Biology	Contemporary ecological factors and historical evolutionary factors influencing the distribution and abundance of arid-zone reptile species in space and time	Nil	M Cowan
West Australian Biogeochemistry Centre, CSIRO Earth Science and Resource Engineering, BHP Billiton	Hydrogeochemistry of Walyarta Springs	\$120,000 over two years	J Rutherford
Western Australian Marine Science Institute, The University of Western Australia	Long-term monitoring of sea-grass communities on behalf of the Cockburn Sound Management Council	\$55,000	M Rule
Western Australian Marine Science Institute	Project 1.1.1 - Distribution and predictors of benthic biodiversity	\$31,000	J Huisman
Western Australian Marine Science Institute	Industry-Government Environmental Meta-database (IGEM)	Nil	S Field, F Mayer

Partners	Project Title	External Funding	Parks and Wildlife Involvement
Western Australian Marine Science Institute	Project 1.2.3: Saltwater crocodiles (<i>Crocodylus porosus</i>) in the north-west Kimberley	\$30,000	A Halford
Western Australian Marine Science Institute	WAMSI Project 1.2.2. Key biological indices required to understand and manage nesting sea turtles along the Kimberley coast	\$1,200,000	S Whiting, T Tucker
Western Australian Museum	NatureMap: data sharing and joint custodianship	Nil	P Gioia
Western Australian Museum	Kimberley island biodiversity asset identification	Nil	L Gibson
Western Australian Museum	Woodside Collection Project (Kimberley)	Nil	J Huisman
Western Australian Museum	Pilbara biological survey	Nil	A Pinder, L Gibson, M Lyons, AH Burbidge

Current Collaboration with Academia (Student Projects)

Parks and Wildlife Officer	Student	Academic	Project Title	Duration	Page
D Algar	F Morcombe (BSc (Honours))	Dr H Mills (The University of Western Australia)	Population estimate and habitat of the Christmas Island Hawk-owl (<i>Ninox natalis</i>)	2015 – 2016	123
D Algar	S Comer (PhD)	Dr D Roberts (The University of Western Australia), Dr P Speldewinde (The University of Western Australia)	Ecology of the feral cat (<i>Felis catus</i>) in coastal heaths of the south coast of Western Australia	2014 – 2021	123
D Algar	N Dybing (PhD)	Dr P Adams (Murdoch University)	Parasites and diet of feral cats and rodents on mainland Western Australia and offshore Islands (Christmas Island and Dirk Hartog Island)	2012 – 2016	124
N Burrows	M Wysong (PhD)	Dr E Ritchie (Melbourne University), Prof R Hobbs (The University of Western Australia)	The ecology and interactions of dingoes and feral cats in the arid Rangelands of Western Australia	2012 – 2015	125
M Byrne	A Lullfitz (PhD)	Prof SD Hopper (The University of Western Australia)	Vegetation responses to Noongar land management practices in old and young landscapes	2014 – 2018	125
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 southwest Western Australia	2014 – 2015	126
R Evans	C Tuckett (PhD)	Dr T Wernberg (The University of Western Australia), Dr T de Bettignies (The University of Western Australia)	Improving our understanding of high latitude coral communities in temperate Western Australia: biogeography, latitudinal growth patterns, connectivity-fecundity-recruitment and competitive tolerance to seaweeds	2015 – 2017	127
R Evans	M Moustaka (BSc (Honours))	Dr T Langlois (The University of Western Australia)	The impacts of suspended sediment on fish assemblage structure in north-west Australia	2016 – 2016	128
T Holmes	B Vaughan (MSc)	Dr T Langlois (The University of Western Australia), D McLean (The University of Western Australia)	Assessing the drivers of fish distribution patterns within the Ningaloo Marine Park, Western Australia	2015 – 2017	128

Parks and Wildlife Officer	Student	Academic	Project Title	Duration	Page
T Holmes	D Collins (BSc (Honours))	D McLean (The University of Western Australia), Dr T Langlois (The University of Western Australia)	A novel stereo-video method to investigate fish-habitat relationships	2014 – 2016	129
A Kendrick	A Turco (PhD)	A/Prof G Hyndes (Edith Cowan University)	The role of <i>Kyphosus</i> spp. in reef ecosystems	2012 – 2015	129
L Mccaw	H Etchells (BSc (Honours))	Prof P Grierson (The University of Western Australia)	Recovery of karri forest after an extreme wildfire in Northcliffe.	2016 – 2016	130
D Coates, MA Millar	R Fernandes (MSc)	Dr G Oostermeijer (University of Amsterdam)	Ecological genetic assessment of <i>Hakea laurina</i> in restoration sites compared with remnant bush	2015 – 2017	130
K Morris	K Bettink (PhD)	Dr H Mills (The University of Western Australia)	Ecology and taxonomic differentiation in the Australian water rat and implications for its conservation status in Western Australia	2010 – 2016	131
K Morris	R Thavornkanlapachai (PhD)	Dr H Mills (The University of Western Australia)	Genetic consequences of mammal translocations in Western Australia using case studies of dibblers, boodies and black-flanked rock wallabies	2011 – 2016	132
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 for waterbirds between different wetland suites within the Lake Warden wetland system	2013 –	132
K Thiele	T Hammer (PhD)	Prof L Mucina (The University of Western Australia)	Phylogeny, systematics and evolution of the Australian arid-zone <i>Ptilotus</i>	2015 – 2018	133
K Thiele	B Anderson (PhD)	Prof P Grierson (The University of Western Australia), Dr M Barrett (Botanic Gardens and Parks Authority)	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	133
K Thiele	S Randell (BSc (Honours))	Prof P Grierson (The University of Western Australia)	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	134
A Wayne	A Worth (PhD)	Dr T Flemming (Murdoch University), Prof A Thompson (Murdoch University), A/Prof A Lymbery (Murdoch University)	The role of <i>Toxoplasma gondii</i> in declining populations of the woylie (<i>Bettongia penicillata ogilbyi</i>)	2011 – 2015	135
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	135

Parks and Wildlife Officer	Student	Academic	Project Title	Duration	Page
A Wayne	A Barrett (BSc (Honours))	Dr M Calver (Murdoch University)	Population estimates of the threatened western ringtail possum (<i>Pseudocheirus occidentalis</i>) and common brushtail possum (<i>Trichosurus vulpecula</i>) in conservation and harvested forests of southwestern Australia.	2014 – 2016	136
A Wayne	G Yeatman (PhD)	Dr H Mills (The University of Western Australia)	Wildlife ecology in the southern jarrah forest	2011 – 2016	136
A Wayne	S Hing (PhD)	Prof A Thompson (Murdoch University), Dr S Godfrey (Murdoch University), Dr E Narayan (Charles Sturt University)	Stress and disease in critically endangered woylies (<i>Bettongia penicillata</i>)	2014 – 2016	137
A Wayne	K Skogvold (PhD)	Dr K Warren (Murdoch University), Dr S Vitali (Murdoch University), Dr C Holyoake (Murdoch University), Dr C Monaghan (Murdoch University)	A comparative health and disease investigation in the woylie: captive vs free-range enclosure vs wild	2010 – 2015	138
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	138
A Wayne	A Atkinson (PhD)	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	139
A Wayne	U Parkar (PhD)	Prof A Thompson (Murdoch University), A/Prof A Lymbery (Murdoch University)	Genetic diversity of <i>Blasitocystis isolates</i> found in West Australian native fauna	2013 – 2015	140
A Wayne	K Bain (PhD)	A/Prof R Bencini (The University of Western Australia)	Ecological study of the quokka (<i>Setonix brachyurus</i>) in the southern forests of south-west Western Australia	2006 – 2015	140
S Whiting	P Wilson (PhD)	Dr M Thums (Australian Institute of Marine Science), Dr C Pattiaratchi (The University of Western Australia), Dr M Meekan (Australian Institute of Marine Science)	Understanding the early offshore movement of flatback turtle hatchlings and the effects of anthropogenic light	2015 – 2019	141
S Whiting	Dr E Young (PhD)	Dr R Vaughan-Higgins (Murdoch University), Dr N Stephens (Murdoch University), Dr K Warren (Murdoch University), Dr L Yeap (Murdoch University)	The health status of marine turtles in northern and western Australia	2016 – 2016	142
S Whiting	J Stuart (PhD)	Dr T Fleming (Murdoch University), B Bateman (Curtin University), Dr P Adams (Murdoch University)	Evidence based management of foxes adjacent to turtle beaches in Western Australia	2016 – 2019	142

Parks and Wildlife Officer	Student	Academic	Project Title	Duration	Page
S Whiting	B Bentley (BSc (Honours))	Dr N Mitchell (The University of Western Australia), Dr J Kennington (The University of Western Australia), Dr O Berry (CSIRO)	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	143
S Wilson	J Van Lier (PhD)	Dr C Fulton (Australian National University), Dr M Depczynski (Australian Institute of Marine Science)	The effect of patch habitat networks in shaping the distribution, abundance and diversity of coastal fishes	2015 – 2018	143
S Wilson	J Goetze (PhD)	Dr T Langlois (The University of Western Australia)	Variation in the intensity of periodic harvests in Fijian tabu areas and the effect on reef fish assemblages	2012 – 2015	144
S Wilson	C Desfosses (PhD)	N Loneragan (Murdoch University), H Lozano (CSIRO)	The significance of macroalgae to the diets of juvenile fishes and the ecosystem function of the Ningaloo Reef lagoon	2015 – 2016	144
S Wilson	K Bennett (PhD)	Dr T Langlois (The 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	145

Student Projects

Population estimate and habitat of the Christmas Island Hawk-owl (*Ninox natalis*)

STP 2016-021

Parks and Wildlife Scientist

D Algar

Student

F Morcombe (BSc (Honours))

University Academics

Dr H Mills (The University of Western Australia)

Progress Report

This study aimed to determine a current and accurate habitat-based population estimate of the Christmas Island hawk-owl (*Ninox natalis*), an endemic species of Christmas Island that is currently listed as Vulnerable (IUCN 2013). Owls were surveyed across five habitat types using call playback. The location data was analysed to calculate an overall population estimate based on owl territories per km² from estimated habitat densities. The call playback survey was conducted three times and covered approximately 42% of Christmas Island. Hawk-owls were present in 170 of the 402 survey site visits (approximately 40%) over the three surveys. The habitat class closed canopy rainforest had the highest average owl territory density with 1.91 hawk-owl territories per km². The lowest density habitat class was non-vegetated areas (such as mine sites and settlement areas) with 0.41 hawk-owl territories per km². The densities of the five habitat classes were extrapolated across the entire island to produce a total population estimate of 342 mature individuals. This current population estimate is significantly lower than past estimates of approximately 1000 mature individuals. Consequently it is recommended that the owl's current IUCN conservation classification be upgrading from Vulnerable to Endangered.

The thesis was submitted for examination in May 2016.

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

STP 2016-018

Parks and Wildlife Scientist

D Algar

Student

S Comer (PhD)

University Academics

Dr D Roberts (The University of Western Australia), Dr P Speldewinde (The University of Western Australia)

Progress Report

This project will be the first major study of feral cat (*Felis catus*) ecology in the coastal heaths of the south coast of Western Australia. The project is investigating habitat use, movement, dietary preferences and prey availability in important conservation reserves of the region, the relationship of landscape fragmentation to these factors, and building on work completed through the South Coast Integrated Fauna Recovery Project (IFRP) in order to provide essential information for optimising the effectiveness of control programs for this introduced predator in south coast ecosystems.

Progress to date has seen samples from feral cats collected from nature reserves and national parks across the south coast region, and on conservation properties managed by Bush Heritage in the Gondwanalink Fitz-Stirling corridor. Stomach contents analysis has been completed for 40 animals, and samples collected from over 100 individuals for stable isotope work. Analysis of GPS collar data collected from cats collared in the IFRP project, and from nature reserves and Bush Heritage properties in the Fitz-Stirling's corridor has commenced, with data from collars to be used to assess habitat use and resource area dependency. Eighteen monitoring sessions have been completed for use in a prey availability modelling study.

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

STP 2012-202

Parks and Wildlife Scientist

D Algar

Student

N Dybing (PhD)

University Academics

Dr P Adams (Murdoch University)

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.

Two papers have been published in *Vector Borne Zoonotic Dis* and *Parasitology Open*

An additional chapter (Challenging the dogma of the 'island syndrome': A study of helminth parasites of feral cats and black rats on Christmas Island) has been submitted as an invited chapter for the book "Wildlife Conservation Management on Inhabited Islands".

This thesis is nearly finalised and the project is complete.

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

STP 2014-016

Parks and Wildlife Scientist

N Burrows

Student

M Wysong (PhD)

University Academics

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

Progress Report

The aims of this project were to enhance the understanding of dingo and feral cat interactions in arid Australia and to help inform the management of dingos and feral cats to deliver cost effective biodiversity conservation outcomes in the rangelands.

This work has shown that camera traps on tracks achieved robust estimates of occupancy in a modelling framework that accounted for imperfect detectability and provided estimates of detectability for all target species. Using GPS and satellite telemetry, it was shown that dingoes selection of woodland habitat and feral cats selection of grasslands was probably related to prey availability and preferred vegetation cover, rather than their interactions *per se*. There was no evidence that feral cats avoided landscape features used by dingoes, and there was no temporal separation. This information will assist in the development of future cat and dingo baiting strategies.

This PhD project has been completed and will be submitted for examination in August 2016.

Vegetation responses to Noongar land management practices in old and young landscapes

STP 2016-001

Parks and Wildlife Scientist

M Byrne

Student

A Lullfitz (PhD)

University Academics

Prof SD Hopper (The University of Western Australia)

Progress Report

This project aims to improve our understanding of the nexus between Noongar culture and contemporary floristic distributions, ultimately informing both biodiversity conservation in the South-west Australian Floristic Region (SWAFR) and connection of Noongar people with country. Through collaborative research with southern coastal Noongar Elders and archaeologists, the project explores how specific cultural activities may have influenced biodiversity within the SWAFR through a series of investigations examining vegetation patterns and processes. Specific areas of focus include testing for evidence of Noongar plant resource concentration around cultural nodes and botanical differentiation between nodes of varying historic cultural use; phylogeographical investigation of culturally important taxa in the genus *Platysace*; investigations of resource concentration effects of edible *Platysace tuber* harvest; and an analysis of Noongar land use patterns in relation to landscape age and propensity to disturbance.

Phylogeographical work aims to test a hypothesis that humans are a historical vector influencing the distribution of the staple Noongar food species, *Platysace deflexa* and *Platysace trachymenioides*. To date, a total of 761 individuals of *Platysace deflexa*, *P. trachymenioides*, *P. effusa*, *P. maxwellii*, *P. compressa* and *P. juncea* have been sampled at 105 sites located in inland areas southwest of a line from Northampton to the Cape Arid National Park. DNA extraction from leaf matter has commenced, eight noncoding chloroplast DNA regions have been evaluated, and three regions, comprising trnS-trnG52S, trnV-ndhc and psbD-trnT, selected for use in analysis. DNA extraction, polymerase chain reaction and sequencing are currently underway for selected sampled individuals.

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

STP 2015-010

Parks and Wildlife Scientist

D Coates, K Thiele

Student

L Craft (BSc (Honours))

University Academics

Prof L Mucina (The University of Western Australia)

Progress Report

This project investigated the evolutionary consequences and conservation significance of hybridization between *Styliidium 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 assessed if there are morphological patterns in flower shape and differences in ecological features that distinguish the two parental taxa and the hybrids, and utilised molecular markers to confirm the status of putative hybrids and whether any populations represent separate hybrid derived species. The study found that there was a complex pattern of hybridization between the two species with genetic, morphological and ecological evidence for past hybridization events and current hybridization occurring at some sites, but insufficient evidence to confirm that some populations represent a separate hybrid derived species.

Improving our understanding of high latitude coral communities in temperate Western Australia: biogeography, latitudinal growth patterns, connectivity-fecundity-recruitment and competitive tolerance to seaweeds

STP 2015-005

Parks and Wildlife Scientist

R Evans

Student

C Tuckett (PhD)

University Academics

Dr T Wernberg (The University of Western Australia), Dr T de Bettignies (The University of Western Australia)

Progress Report

This project will establish baseline data for high latitude coral community dynamics across broad latitudinal and associated temperature gradients. A multidisciplinary approach will involve experimental studies, spatial and temporal analysis, molecular and histological techniques to determine variation in corals and their suitability to temperate systems. Study locations will be chosen to represent specific temperature gradients across tropical, warm temperate and cool temperate latitudes. Study species will represent more temperate or cosmopolitan species found in Western Australia, which will be determined from previous and current studies. The objectives of this project are to:

1. Explore the biogeographical patterns of coral distribution from tropical into temperate areas to establish a point of reference for future change.
2. Determine phenotypic plasticity and population fitness across latitudinal and associated temperature gradients in important population parameters, including growth, fecundity, recruitment, connectivity and competitive tolerance to seaweeds.
3. Examine the environmental suitability of temperate reefs as refugia for corals under elevated ocean temperatures.

During 2015/16 all demographic data has been collected and analyses have commenced, coral settlement tiles have been deployed at Marmion Marine Park for over one year, coral tiles were deployed and retrieved at two other locations and coral (*Turbinaria mesenterina*) genetic samples were collected from Mindarie.

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

STP 2016-006

Parks and Wildlife Scientist

R Evans

Student

M Moustaka (BSc (Honours))

University Academics

Dr T Langlois (The University of Western Australia)

Progress Report

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

During 2015/16, the project proposal was finalised and fieldwork undertaken to collect benthic and fish data. Analyses of these data is now underway.

Assessing the drivers of fish distribution patterns within the Ningaloo Marine Park, Western Australia

STP 2016-014

Parks and Wildlife Scientist

T Holmes

Student

B Vaughan (MSc)

University Academics

Dr T Langlois (The University of Western Australia), D McLean (The University of Western Australia)

Progress Report

This project examined the influence of fishing on fish assemblages across the reef slope and deeper water areas of Ningaloo Marine Park. The study compared fish communities in sanctuary zones and fished areas using stereo-baited remote underwater video methods. The findings indicated that the abundances of targeted fish populations inside and outside of sanctuary zones were variable, with limited evidence to suggest positive sanctuary zone effects at these depths. It is likely that habitat related characteristics are a greater driver of fish assemblages under current conditions. Fish communities were heavily stratified by depth, indicating that multiple depth gradients should be incorporated into marine park planning and monitoring processes. As such, this body of work represents a significant contribution to science-based management within the Ningaloo Marine Park. This study was completed during 2016 and the thesis was recently approved. A manuscript describing the project and its findings will be submitted to a peer-reviewed journal in 2017.

A novel stereo-video method to investigate fish-habitat relationships

STP 2016-013

Parks and Wildlife Scientist

T Holmes

Student

D Collins (BSc (Honours))

University Academics

D McLean (The University of Western Australia), Dr T Langlois (The University of Western Australia)

Progress Report

This project investigated the influence of habitat composition and complexity on fish assemblages in the Pilbara. A novel method was developed to obtain habitat complexity information from both current and historical stereo-diver operated video samples collected as part of fish monitoring by the Department in Western Australia's marine parks and reserves. This method now enables habitat related information to be extracted from video collected for fish monitoring purposes, improving the quality of information collected for research and monitoring purposes. This has direct relevance to current monitoring programs, as well as the wider marine science community. The project was completed in late 2015 and a paper was recently accepted for publication in the journal *Methods in Ecology and Evolution*.

The role of *Kyphosus* spp. in reef ecosystems

STP 2012-217

Parks and Wildlife Scientist

A Kendrick

Student

A Turco (PhD)

University Academics

A/Prof G Hyndes (Edith Cowan University)

Progress Report

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

All fieldwork associated with this project at Marmion and Ningaloo Marine Parks has now been completed, including a pilot study 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. Data on habitat use and dietary composition has been analysed, and chapters on habitat associations and diet of different species are now being prepared.

Recovery of karri forest after an extreme wildfire in Northcliffe.

STP 2016-016

Parks and Wildlife Scientist

L Mccaw

Student

H Etchells (BSc (Honours))

University Academics

Prof P Grierson (The University of Western Australia)

Progress Report

This Honours project seeks to enhance understanding of the ecological response of karri forest to bushfire, focussing on the recovery of mature karri and marri trees and seedling recruitment and survival following the large O'Sullivan bushfire of February 2015. The study will test the hypotheses that with increasing fire severity, overstorey trees will exhibit higher levels of seedling recruitment and lower levels of epicormic resprouting, and that high severity fire will result in a more homogenous understorey dominated by plant species that are ephemeral or have attributes that make them successful as disturbance opportunists. Nine study sites were established in March 2016 sampling unburnt forest and forest burnt at low and high severity, as determined by crown scorch and defoliation. At each site, all trees within a 30 m x 30 m quadrat were measured for stem diameter and crown condition, and understorey species composition determined in five 4m² quadrats. Soil samples were also collected for assay of carbon, nitrogen and carbon isotope signatures.

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

STP 2016-010

Parks and Wildlife Scientist

D Coates, MA Millar

Student

R Fernandes (MSc)

University Academics

Dr G Oostermeijer (University of Amsterdam)

Progress Report

This project is part of a larger ARC Linkage Project entitled 'Is restoration working? An ecological assessment'. The aims of the project are to assess and compare insect flower visitors, levels of genetic diversity and the mating system for restored and natural remnant populations of *Hakea laurina*. Leaf and seed material has been collected from restoration and remnant populations at two Gondwana Link sites. Insect flower visitors have been sampled from the same sites and are being identified. DNA has been extracted from leaf material, seedlings have been germinated and seedling DNA extractions are underway. Microsatellite primers are being tested for the assessment of genetic diversity and mating systems in *H. laurina*.

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

STP 2013-060

Parks and Wildlife Scientist

K Morris

Student

K Bettink (PhD)

University Academics

Dr H Mills (The University of Western Australia)

Progress Report

This project represents the first research to document genetic divergence across the range of the water rat, or rakali, *Hydromys chrysogaster*, and addressed voids in understanding the status of Western Australian populations. Results were evaluated in the context of ecological trait, and geographical and temporal isolation, driven by aridification of continental Australia and changing sea levels during Pliocene and Pleistocene epochs. Findings supported taxonomic revision within *Hydromys* to at least subspecific level, delineation of a new *Hydromys* / *Parahydromys* species, and due to high genetic structuring, treatment of certain regional populations as evolutionarily significant units (ESUs). These outcomes will help guide effective conservation and management of this Priority species and all its ECUs into the future.

This project has been completed and a thesis was submitted in March 2016.

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

STP 2012-221

Parks and Wildlife Scientist

K Morris

Student

R Thavornkanlapachai (PhD)

University Academics

Dr H Mills (The University of Western Australia)

Progress Report

This project investigated genetic factors that could contribute to improved fauna translocation success. The study highlighted the importance of incorporating knowledge of fine-scale genetic structure when sampling wild individuals for captive breeding and translocation programs. Using examples of dibbler and boodie translocations, the outcomes of genetic mixing of founder stocks has added to rare empirical studies of marsupial translocations founded from multiple sources. Genetic mixing has been shown to benefit the newly established populations of dibblers and boodies. Increased levels of genetic diversity and reduced genetic relatedness among offspring were reported. However they also showed a significant reduction in the effective population size as a result of founder effects. This study has shown that population lineages within newly established populations are prone to changes from mortality and / or reproductive variance among founders and release strategies. Therefore, genetic monitoring is important, not only for assessing translocation success, but also for determining whether supplementation of managed populations is required.

The thesis was completed and submitted in February 2016, the project is now finished.

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

STP 2013-013

Parks and Wildlife Scientist

A Pinder

Student

J Lizamore (PhD)

University Academics

Dr R Vogwill (The University of Western Australia)

Progress Report

The scope of the project has changed from a numerical orientated hydrological and geochemical model of wetland suites to a simpler one focusing on specific lakes in the Lake Warden wetland system. Analysis of aquatic invertebrates from the pink lakes component of the wetland system has been undertaken, and analysis of evaporative total dissolved solids was completed. A paper on the management of the Lake Warden system was presented at the South Australia NRM Conference in Adelaide.

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

STP 2015-012

Parks and Wildlife Scientist

K Thiele

Student

T Hammer (PhD)

University Academics

Prof L Mucina (The University of Western Australia)

Progress Report

This project has established a research program designed to address three key questions on the evolution of *Ptilotus*:

1. what are the phylogenetic patterns in the genus particularly with respect to its closest relative *Aerva*, and the biogeographic and ecological correlates of clades in the group;
2. how have adaptations to different pollinator guilds driven speciation and radiation in Australian *Ptilotus*; and
3. how have *Ptilotus* species adapted to low soil phosphorus in Australia over evolutionary time.

Early results include recognition of a new genus to accommodate an anomalous and phylogenetically disjunct species from the Arabian Peninsula previously included in *Aerva*, and taxonomic resolution of species boundaries in the geographically widespread and iconic Australian species *P. exaltatus* and *P. nobilis*.

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

STP 2015-013

Parks and Wildlife Scientist

K Thiele

Student

B Anderson (PhD)

University Academics

Prof P Grierson (The University of Western Australia), Dr M Barrett (Botanic Gardens and Parks Authority)

Progress Report

This project has substantially resolved species limits in the difficult *Triodia basedowii* species complex, which has a centre of taxonomic diversity in the Pilbara and has previously posed intractable taxonomic problems for ecological survey, mine-site restoration and conservation planning. The project has: improved our understanding of the taxonomic, ecological and geographic limits of the named taxa *T. basedowii*, *T. lanigera*, *T. concinna* and *T. plurinervata*; resolved ready for formal naming the phrase-named species *T.sp.* Shovelanna Hill (S. van Leeuwen 3835), *T. sp.* Little Sandy Desert (S. van Leeuwen 4935), *T. sp.* Peedamulla (A.A. Mitchell PRP 1636), *T. sp.* Warrawagine (A.L. Payne PRP 1859) and *T. sp.* Pannawonica (B.M. Anderson & M.D. Barrett BMA 89); and discovered and characterised three new species. All species will be formally described in a forthcoming taxonomic revision of the group. In addition, the project has provided new knowledge on the evolutionary history of the Pilbara and of arid Australia based on phylogenetic and biogeographic patterns in the species complex.

This project will finish in July 2016 with submission of a PhD thesis.

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

STP 2015-011

Parks and Wildlife Scientist

K Thiele

Student

S Randell (BSc (Honours))

University Academics

Prof P Grierson (The University of Western Australia)

Progress Report

This project set out to determine whether *Banksia* species in south-west Western Australia show evidence of predicted range contraction or physiological stress since the 1980s in response to observed climate change (particularly a significant reduction in winter rainfall) in the region since that time. Two arms of the project were:

1. a highly successful citizen science campaign that mobilised volunteers to revisit target sites where six key *Banksia* species were recorded during the mid-1980s *Banksia Atlas* project; and
2. a physiological study that measured carbon isotope ratios in leaf samples along a climate gradient to assess levels of water stress.

Key findings from the project showed one species, *B. grandis*, appears to show a clear signal of southward contraction but no clear evidence yet of range contraction in the other five of the six species studied. Most species appear to be physiologically well-adapted to their climate gradient.

The project is now complete.

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

STP 2012-229

Parks and Wildlife Scientist

A Wayne

Student

A Worth (PhD)

University Academics

Dr T Flemming (Murdoch University), Prof A Thompson (Murdoch University), A/Prof A LyMBERY (Murdoch University)

Progress Report

A very low sero-prevalence (~5%) of *Toxoplasma gondii* antibodies in wild woylies limited efforts to investigate whether *T. gondii* affects woylie behaviour. The laboratory mouse studies found limited evidence for an effect of *T. gondii* on mouse behaviour when average levels of behavioural traits were considered, although this may have been due to low statistical power and/or variable outcomes of infection between individual mice. Exposure to *T. gondii* is associated with decreased repeatability of 'activity in the elevated plus maze (EPM)' appears to be due to baseline dependent effects of *T. gondii* exposure on behaviour; individuals that started with low 'activity in the EPM' tended to increase their activity over time post-infection and *vice versa*. It is hoped that this novel finding will encourage future studies to consider individual differences in behaviour. This will ultimately have benefits for understanding the behavioural effects of *T. gondii* infection in a range of species, and can be applied to future research concerning the effect of *T. gondii* on woylie behaviour. Three posters and one oral presentation have been presented at conferences. Two scientific journal articles have been published, and two more are in preparation.

The project has been completed and the thesis submitted.

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

STP 2014-008

Parks and Wildlife Scientist

A Wayne

Student

A Northover (PhD)

University Academics

Prof A Thompson (Murdoch University)

Progress Report

This project evaluates how fauna translocations impact the transmission of parasites in woylies, and what consequences this has for translocated hosts and other cohabiting species. In June 2014, 182 woylies were translocated from Perup Sanctuary to two unfenced sites in Kingston National Park in the Upper Warren region (UWR). In June 2015, 69 woylies were translocated from the UWR into Dryandra Woodland.

Pre- and post-translocation, woylies from both the source and destination sites have been monitored and blood, ectoparasite and faecal samples collected. In each destination site, cohabiting mammal species were also sampled. To evaluate the effect of anti-parasite treatment, we treated half the woylies with Ivermectin prior to translocation. Data collection is now complete and sample analysis is underway. The first anti-parasite treatment trial were published in *Ecohealth* and showed that a single subcutaneous dose of ivermectin (0.2mg/kg) temporarily reduced Strongyloides-like egg counts in woylies post-translocation. There was no effect of treatment in other target or non-target gastrointestinal parasites, and no benefit of treatment to host health. Instead, translocation-induced perturbations to population density were influential in driving parasite abundance and shaping host health.

Population estimates of the threatened western ringtail possum (*Pseudocheirus occidentalis*) and common brushtail possum (*Trichosurus vulpecula*) in conservation and harvested forests of southwestern Australia.

STP 2015-007

Parks and Wildlife Scientist

A Wayne

Student

A Barrett (BSc (Honours))

University Academics

Dr M Calver (Murdoch University)

Progress Report

The aims of this project were to 1) test the suitability of spotlighting and distance sampling for providing population estimates and trends of western ringtail and brushtail possums; 2) assess the significance of vegetation structure in the detection of possums, and 3) provide a population estimate for possums in the Kingston forest block and Perup Sanctuary.

Results from the project indicate that spotlighting from a vehicle was more efficient than on foot. Density estimates of brushtail possums from spotlighting was lower than those derived from trapping. Results also indicated that vegetation density was significantly greater before compared with after a mild prescribed burn but did not seem to affect possum detection rates. Despite low spotlight detection rates limiting the ability for robust population estimates of possums in the jarrah forest, this remains a better method than trapping for western ringtail possums and a satisfactory complement to trapping for brushtail possums. The thesis was completed in June 2016 and has been submitted for examination.

Wildlife ecology in the southern jarrah forest

STP 2012-230

Parks and Wildlife Scientist

A Wayne

Student

G Yeatman (PhD)

University Academics

Dr H Mills (The University of Western Australia)

Progress Report

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

A report has been completed on the baseline survey of small terrestrial vertebrates in the Perup Nature Reserve. One article describing the home range size and habitat utilisation of woylies in and outside Perup Sanctuary has been published in the journal *Australian Mammalogy*. A second article describing broad-scale habitat association of small vertebrates has been accepted by the *Australian Journal of Zoology*. Three remaining manuscripts have been prepared and submitted to journals for publication.

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

STP 2014-010

Parks and Wildlife Scientist

A Wayne

Student

S Hing (PhD)

University Academics

Prof A Thompson (Murdoch University), Dr S Godfrey (Murdoch University), Dr E Narayan (Charles Sturt 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 Parks and Wildlife 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.

All field and laboratory work has been completed and the majority of statistical analyses has been performed. We have published a paper on the relationship between woylie stress physiology, immune function and parasite infection. Another paper investigating factors that influence woylie stress physiology is in review and one on woylie physiology during translocation is in preparation.

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

STP 2013-016

Parks and Wildlife Scientist

A Wayne

Student

K Skogvold (PhD)

University Academics

Dr K Warren (Murdoch University), Dr S Vitali (Murdoch University), Dr C Holyoake (Murdoch University), Dr C Monaghan (Murdoch University)

Progress Report

The project contributes to the investigation of the role of disease in the declines and lack of recovery of the woylie. Health testing of three contrasting population management systems was conducted over a two year period from October 2010 to November 2012. Significant findings include: a novel herpesvirus at low prevalence; low prevalence of exposure to Macropodid herpesviruses; no exposure to *Toxoplasma gondii* detected in the samples tested; and no exposure to Wallal & Warrego orbiviruses detected in the samples tested. Papers are underway for the thesis by publication consisting of: general health and haematology & biochemistry reference ranges; infectious disease screening; and use of novel health assessment techniques such as measuring glucocorticoids and anti-oxidants. Hair cortisol analysis was completed in May 2016. Two co-authored papers have been published and one primary author paper is near submission.

Outcomes from this project include:

- an extensive assessment of the health and disease status of woylies in two wild populations in the Upper Warren region and the insurance population at Perup Sanctuary;
- baseline reference ranges for woylie health and diseases for future wildlife health and disease work; and
- several disease agents previously identified as potentially high risk factors that may influence the decline and recovery of woylie populations were they to be present have been assessed and are currently considered not to pose a risk.

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

STP 2014-009

Parks and Wildlife Scientist

A Wayne

Student

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 woylie decline; thus, characterising factors influencing pathogen transmission is the focus of this project. We are also investigating the impact of perturbations (habitat expansion and fire) on woylie behavior, social structure, and health. GPS collars were used to monitor woylies in a predator-proof reserve, Whiteman Park; 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. All these factors will be considered in light of perturbation effects.

Fieldwork for this project finished in February 2016. Laboratory work has commenced and should be completed by August 2016.

Validating management options for maximising genetic success in translocation programs for the Woylie (*Bettongia penicillata ogilbyi*)

STP 2015-014

Parks and Wildlife Scientist

A Wayne

Student

A Atkinson (PhD)

University Academics

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

Progress Report

This project explored and validated management options for increasing genetic diversity in translocated populations. Using the woylie (*Bettongia penicillata ogilbyi*) as a model species it examined the effectiveness of founder selection and population supplementation. This study identified that the genetic diversity of a founding population could be more efficiently captured using a spatially-designed sampling regime. 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 preliminary results obtained in this study indicate that the developed models had the tendency of overestimating the genetic diversity that could be achieved through a supplementation program. This may be possibly caused

by animals used in supplementation being reproductively ineffective, or simply not surviving long enough to contribute genetically to the population. These results have implications for the ongoing management of woylie populations and highlight the important contribution that genetic monitoring can make to the science of reintroduction biology.

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

STP 2013-018

Parks and Wildlife Scientist

A Wayne

Student

U Parkar (PhD)

University Academics

Prof A Thompson (Murdoch University), A/Prof A Lymbery (Murdoch University)

Progress Report

Prior to this study, limited data was available regarding the prevalence and molecular characterization of *Blastocystis* in free-ranging and wild Australian native fauna. Faecal samples from four species were examined for the presence of *Blastocystis*. The overall prevalence of *Blastocystis* was 32.5%, and five different genetic groups (subtypes) were found. *Blastocystis* was detected in all locations sampled, with its prevalence and genetic diversity greatest in the Upper Warren Region compared to the fenced locations. In order to screen these samples for multiple GI parasitic infections, a multiplex PCR was developed to screen samples for *Blastocystis*, *Giardia duodenalis* and *Cryptosporidium* sp. simultaneously. This multiplex PCR was tested against singleplex PCRs and microscopy, and was found to be equally sensitive or to have greater sensitivity than the singleplex PCRs, and it has greater sensitivity and specificity than microscopy. The thesis has been submitted and has recently been accepted. Two papers are in preparation for publication.

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

STP 2012-225

Parks and Wildlife Scientist

A Wayne

Student

K Bain (PhD)

University Academics

A/Prof R Bencini (The University of Western Australia)

Progress Report

Occupancy models identified the density of the near-surface fuel layer, vegetation structure and proximity to a different fuel age as the variables that best predict the probability of occupancy of habitat used by quokkas. Associated monitoring indicated that feral cats were responsible for almost complete recruitment failure over a four year period due to predation of young immediately after pouch emergence. Mean home range of 71 ha (core range 18 ha) with movements of up to 10 km/night were found. 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 14.2 km, using riparian vegetation as corridors. Factors driving the recolonisation of burnt areas by quokkas following fire were investigated. Retention of vertical vegetation structure, more than 20% of the area unburnt, and multiple unburnt pockets larger than 36 ha and within 1 km of at least two other pockets were found to be important for rapid recolonisation of fire-affected areas by quokkas. The application of fire to achieve these outcomes was dependent on high surface moisture (>11 % Jarrah SMC) and low soil dryness index (<800) and day of burn conditions that contributed to a fire rate of spread of <40 m/hr. Moisture differentials in riparian systems and discontinuous vegetation in rocky outcrops contributed to unburnt refugia under these fire conditions. Intense homogenising wildfire resulted in a complete loss of vertical vegetation structure and a lack of unburnt pockets, which contributed to these areas remaining uncolonised for the duration of the study. Research outcomes relating to quantifiable survey methods, habitat requirements, and fire management have now been published and the PhD thesis has been completed.

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

STP 2016-024

Parks and Wildlife Scientist

S Whiting

Student

P Wilson (PhD)

University Academics

Dr M Thums (Australian Institute of Marine Science), Dr C Pattiaratchi (The University of Western Australia), Dr M Meekan (Australian Institute of Marine Science)

Progress Report

Artificial light influences the orientation of hatchling flatback turtles and is a major pressure affecting this species in Western Australia. This project will investigate the extent of this influence under different light regimes and environmental cues and will quantify the impacts of light on turtles in the wild. The aims of the project are to: 1) determine if flatback turtle hatchlings are attracted to different types of light when in-water and for how long using acoustic telemetry, whilst concurrently looking at what natural cues (e.g. currents and waves) they may be using to initially move offshore; 2) determine if flatback turtle hatchlings use wave cues to move offshore, and explore the relationship between light cues and wave cues in a wave tank for both flatback and green turtle hatchlings, and 3) examine the relationship between distance from light source and hatchling attraction, as well as what effect lingering around light sources on permanent structures has on the predation rates of flatback hatchlings.

The first field study was successfully completed with the nearshore movements of flatback hatchlings tracked using an acoustic array at Thevenard Island. Wave tank experiments have been trialed to determine the influence of cues such as light, wave angle and wave height, on the orientation of hatchlings in the water.

The health status of marine turtles in northern and western Australia

STP 2016-022

Parks and Wildlife Scientist

S Whiting

Student

Dr E Young (PhD)

University Academics

Dr R Vaughan-Higgins (Murdoch University), Dr N Stephens (Murdoch University), Dr K Warren (Murdoch University), Dr L Yeap (Murdoch University)

Progress Report

This project commenced in 2016 and will assess the health and disease status of flatback turtles throughout Western Australia. This project will investigate dead and injured turtles stranded along the coast and use techniques such as blood chemistry to assess the health of wild turtles. Parasite infections and fibropapilloma virus will be specifically investigated. Although focused on flatback turtles, other species will be included in the study as the opportunities arise.

Evidence based management of foxes adjacent to turtle beaches in Western Australia

STP 2016-025

Parks and Wildlife Scientist

S Whiting

Student

J Stuart (PhD)

University Academics

Dr T Fleming (Murdoch University), B Bateman (Curtin University), Dr P Adams (Murdoch University)

Progress Report

This project will investigate fox biology, distribution and seasonality in relation to their predation of turtle nests. Predation by foxes is a key pressure acting on some turtle rookeries and this study will provide knowledge to inform the long-term management of foxes and turtles. The project commenced in early 2016 and field sites are being identified.

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

STP 2014-014

Parks and Wildlife Scientist

S Whiting

Student

B Bentley (BSc (Honours))

University Academics

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

Progress Report

This project is part of the WAMSI Kimberley node turtle project and is investigating climate change impacts on turtle nesting using prediction and hind-casting models. In 2015/16 egg collections were undertaken at the Lacepede Islands and Eighty Mile Beach and fieldwork is now mostly complete. Additional genomic work will be completed in the laboratory this year. Progress on this project is proceeding as planned.

The effect of patch habitat networks in shaping the distribution, abundance and diversity of coastal fishes

STP 2015-006

Parks and Wildlife Scientist

S Wilson

Student

J Van Lier (PhD)

University Academics

Dr C Fulton (Australian National University), Dr M Depczynski (Australian Institute of Marine Science)

Progress Report

Seaweed-dominated habitats occur in tropical reef systems, where they play vital roles in supporting key species and processes. Habitat quality in seaweed patches, measured as canopy height, holdfast density or percentage cover, varies seasonally and can be a major driver of the presence and abundance of key functional and taxonomic fish groups. However, the relative influence of other seascape variables, such as patch shape, size and proximity, remains poorly understood. This project will study seaweed habitats in the Ningaloo Marine Park, building on research in the region that has highlighted the importance of seaweed microhabitat and intra-patch structure by including patch and inter-patch measures. The study will focus on fishes of the family Labridae (Wrasses and Parrotfishes), which are a diverse group of conspicuous reef fishes, that span a wide range of trophic groups, body sizes, social structures, movement patterns and diel ranges. Specifically the project will: 1) establish how within and between patch habitat structure influences reef fish diversity

within the Ningaloo lagoon; 2) explore how patch habitat configuration influences fish predator-prey dynamics; and 3) quantify how seaweed-associated fish assemblages respond to acute and un-seasonal disturbances in patch-habitat condition.

Over the past year data has been collected on algal and fish communities from macroalgal patches around Coral Bay which will contribute to objectives 1 and 2. In addition an experiment, where macroalgal structure has been altered at several patches, has been established to address objective 3.

Variation in the intensity of periodic harvests in Fijian tabu areas and the effect on reef fish assemblages

STP 2012-235

Parks and Wildlife Scientist

S Wilson

Student

J Goetze (PhD)

University Academics

Dr T Langlois (The University of Western Australia)

Progress Report

Periodically harvested closures (PHCs) are a common form of fisheries management in Melanesia. However it is unclear how effective PHC are in maintaining abundance of target species. This project initially identified suitable methods (diver operated video) and indicators (fish behaviour and biomass) for detecting changes in fish assemblages. Data from field studies in Fiji were then combined with information from the literature and meta analyses used to demonstrate biomass of fish in PHC is greater than in surrounding areas open to fishing. Analyses also found that to be successful, PHCs need to be closed to fishing for a considerable period of time, must be large, old and have high levels of fisher compliance.

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

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

STP 2016-007

Parks and Wildlife Scientist

S Wilson

Student

C Desfosses (PhD)

University Academics

N Loneragan (Murdoch University), H Lozano (CSIRO)

Progress Report

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

During 2015/16, fieldwork was undertaken and fish for dietary analyses were collected and processed. Work has commenced on developing the Ecopath model.

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

STP 2015-003

Parks and Wildlife Scientist

S Wilson

Student

K Bennett (PhD)

University Academics

Dr T Langlois (The University of Western Australia)

Progress Report

The condition of fish and coral communities are often monitored using digital imagery, but the techniques used to collect data differ. Fish data are collected using a forward facing video, whilst coral communities are monitored using cameras that face downward towards the substratum. This project collected forward and downward facing video and compared information from the two methods to assess compatibility of benthic/coral data collected using the two methods. Forward facing video detected more vertically erect coral and canopy forming algae but less turf algae and encrusting corals than the downward facing video. Moreover downward facing video identified more coral genera and fewer corals were unidentifiable, suggesting a higher level of taxonomic resolution is achievable when using downward facing video. There were however strong relationships between the percentages of common benthos recorded by the methods. Thus, stereo video surveys for fish may be considered a potential technique for the description of coral reef benthos but is not necessarily suitable for the monitoring of benthic community assemblages at high taxonomic levels.

A manuscript documenting these findings is currently under review in the journal *Limnology and Oceanography: Methods*.

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Summary of Research Projects

Biogeography

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
Swan, South West	Swan Coastal Plain, Jarrah Forest	Avon	Biological survey and conservation planning for the Swan Coastal Plain bioregion and adjacent scarps (Dandaragan, Darling and Whicher)	3
All Regions	All IBRA Regions	All Regions	Development of ethically acceptable techniques for invertebrate wet-pit trapping	7
Kimberley	Victoria Northern Kimberley, Bonaparte, Dampierland	Rangelands	Kimberley islands biological survey	8
Pilbara	Pilbara	Rangelands	Pilbara region biological survey	9
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Plant species richness and endemism within the south-western Australian Floristic Region	7
Goldfields, Wheatbelt, South Coast, Warren	Murchison, Wheatbelt, Mallee, Esperance Plains, Avon Jarrah Forest	Wheatbelt, Rangelands, South Coast	South-Western Australia Transitional Transect (SWATT)	2
All Regions	All IBRA Regions	All Regions	Western Australian flora surveys	4
All Regions	All IBRA Regions	All Regions	Western Australian terrestrial fauna surveys	5

Animal Science

Parks and Wildlife 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	11
Pilbara, Goldfields	Pilbara, Murchison, Gascoyne	Rangelands	Barrow Island Threatened and Priority fauna species translocation program	20
Midwest	Carnarvon, Yalgoo	Rangelands	Cat Eradication on Dirk Hartog Island	12
Pilbara	Pilbara	Rangelands	Conservation and management of the bilby (<i>Macrotis lagotis</i>) in the Pilbara	17
South Coast, Warren	Jarrah Forest, Esperance Plains, Warren	South West, South Coast	Conservation of south coast threatened birds	24
Goldfields, Swan	Coolgardie, Coastal Plain, Swan	Rangelands, Swan	Conservation of the graceful sun-moth	26
Pilbara	Pilbara	Rangelands	Decision support system for prioritising and implementing biosecurity on Western Australia's islands	15

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page	
Pilbara, Midwest, South Coast	Carnarvon, Desert, Murchison	Gibson Gascoyne,	Rangelands, Swan	Development of effective broad-scale aerial baiting strategies for the control of feral cats	28
Pilbara	Pilbara	Rangelands	Ecology and management of the northern quoll in the Pilbara	25	
Wheatbelt	Avon Wheatbelt	Avon	Feral cat control and numbat recovery in Dryandra woodland and other sites	23	
Pilbara, Swan	Pilbara, Swan Coastal Plain, Jarrah Forest	Rangelands, Swan	Genetic approaches for evaluating the contribution of the reserve system to fauna conservation	19	
Kimberley, Pilbara	Northern Central Kimberley, Dampierland, Pilbara	Kimberley, Kimberley,	Rangelands	Genetic assessment for conservation of rare and threatened fauna	18
South Coast	Jarrah Forest	South Coast	Gilbert's potoroo (<i>Potorous gilbertii</i>) recovery plan	30	
Kimberley	Victoria Northern Ord Central Kimberley	Bonaparte, Kimberley, Victoria Plain, Central Kimberley	Rangelands	Impact of cane toads on biodiversity in the Kimberley	27
All Regions	Gascoyne	All Regions	Improving the use of remote cameras as a survey and monitoring tool	14	
Midwest	Geraldton Sandplains	Rangelands	Monitoring of threatened birds on Dirk Hartog Island	13	
Goldfields	Gascoyne	Rangelands	Rangelands restoration: reintroduction of native mammals to Lorna Glen (Matuwa)	21	

Plant Science and Herbarium

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
All Regions	All IBRA Regions	All Regions	Biodiversity informatics at the Western Australian Herbarium	40
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Biosystematics of fungi for conservation and restoration of Western Australia's biota	34
Midwest	Geraldton Sandplains	Northern Agricultural	Climate change risks for biodiversity and ecosystem function in species-rich shrublands	35
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Development of interactive identification platforms and content	51
Wheatbelt	Avon Wheatbelt, Swan Coastal Plain	Northern Agricultural, Avon, Swan, South Coast	Genetic and ecological viability of plant populations in remnant vegetation	51
Midwest, Wheatbelt, South Coast	Goldfields, Swan, Yalgoo, Murchison, Geraldton Sandplains, Avon Wheatbelt, Coolgardie, Swan Coastal Plain, Mallee, Esperance Plains	Rangelands, Northern Agricultural, Swan, South Coast	North West, Avon, West, genetics and biosystematics for the conservation, circumscription and management of the Western Australian flora	57
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Herbarium collections management	39
All Regions	All IBRA Regions	All Regions	Interactive key and taxonomic studies of Myrtaceae tribe Chamelaucieae	33

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
South Coast	Esperance Plains	South Coast	Is restoration working? An ecological assessment	32
Midwest, Wheatbelt, Swan, South Coast, South West, Warren	Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains	Rangelands, Northern Agricultural, Swan, South Coast	North-West, Avon, West, Mating system variation, genetic diversity and viability of small fragmented populations of threatened flora, and other key plants of conservation importance	54
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	43
All Regions	Great Sandy Desert, Carnarvon, Gascoyne, Geraldton Sandplains, Avon Wheatbelt, Coolgardie, Swan Coastal Plain, Jarrah Forest, Hampton, Mallee, Esperance Plains, Warren	Rangelands, Northern Agricultural, Swan, South Coast	North-West, Avon, West, Seed biology, seedbank dynamics and collection and storage of seed of rare and threatened Western Australian taxa	56
All Regions	All IBRA Regions	All Regions	Strategic taxonomic studies in families including Amaranthaceae and Fabaceae (<i>Ptilotus</i> , <i>Gomphrena</i> , <i>Swainsona</i>) and other plant groups	36
All Regions	All IBRA Regions	All Regions	Systematics of the triggerplant genus <i>Stylidium</i>	47
All Regions	All IBRA Regions	All Regions	Taxonomic resolution and description of new plant species, particularly Priority Flora from those areas subject to mining in Western Australia	50
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 Coast	North-West, Avon, West, Taxonomic review and floristic studies of the benthic marine algae of north-western Australian and floristic surveys of Western Australian marine benthic algae	47
All Regions	Geraldton Sandplains, Avon Wheatbelt, Coolgardie, Swan Coastal Plain, Mallee, Esperance Plains, Warren	Northern Agricultural, Avon, Swan, South West, South Coast	Taxonomic studies on native and naturalised plants of Western Australia arising from biological survey	42
All Regions	All IBRA Regions	All Regions	Taxonomy of selected families including legumes, grasses and lilies	44
All Regions	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren	All Regions	Taxonomy of undescribed taxa in the Ericaceae subfamily Styphelioideae, with an emphasis on those of conservation concern	41
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	46

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
All Regions	All IBRA Regions	All Regions	The Western Australian Herbarium's specimen database	38
All Regions	All IBRA Regions	All Regions	The Western Australian Plant Census and Australian Plant Census	37
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	49
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	55
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	53

Ecosystem Science

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
Warren	Jarrah Forest	South West	Burning for biodiversity: Walpole fine-grain mosaic burning trial	75
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	67
			Development of an environmental risk strategy for sustainable agricultural planning in the Kimberley	59
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	74
	Warren	Northern Agricultural	Fire behavior and fuel dynamics in coastal shrublands	64
Goldfields, Wheatbelt, South Coast	Yalgoo, Avon Wheatbelt, Coolgardie, Mallee	Wheatbelt, Rangelands	Fire regimes and impacts in transitional woodlands and shrublands	72
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	80
Swan	Jarrah Forest	Swan, South West	Hydrological response to timber harvesting and associated silviculture in the intermediate rainfall zone of the northern jarrah forest	79
South West, Warren	Jarrah Forest	Swan, South West	Identification of seed collection zones for rehabilitation	73

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
Swan	Jarrah Forest	Swan	Landscape and fire management interactions and their effects on distribution of invertebrate biodiversity	78
South West	Warren	South West	Long term response of jarrah forest understorey and tree health to fire regimes	65
Swan, Warren	Jarrah Forest, Warren	Swan, South West	Long-term stand dynamics of regrowth forest in relation to site productivity and climate	68
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	69
Kimberley	Northern Kimberley	Rangelands	North Kimberley Landscape Conservation Initiative: monitoring and evaluation	66
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	76
Wheatbelt, South Coast, Warren	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Esperance Plains, Warren	Wheatbelt, Northern Agricultural, Swan, South West, South Coast	Protecting the safe havens: will granite outcrop environments serve as refuges for flora threatened by climate change?	71
Warren	Jarrah Forest, Warren	South West	Responses of terrestrial vertebrates to timber harvesting in the jarrah forest	63
Warren	Warren	South West	Restoring natural riparian vegetation systems along the Warren and Donnelly Rivers	61
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	60

Wetlands Conservation

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
Wheatbelt	Avon Wheatbelt	Avon	Advancing the hydrological understanding of key Wheatbelt catchments and wetlands to inform adaptive management	86
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	83
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)	84
All Regions	All IBRA Regions	All Regions	Taxonomy, zoogeography and conservation status of aquatic invertebrates	87

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
Warren	Warren	South West	Understanding peat wetland resilience: evaluating the impact of climate and land-use change on the hydrodynamics and hydrogeochemistry of peat wetlands in the Warren (Muir-Byenup) District	88
All Regions	All IBRA Regions	All Regions	Western Australian wetland fauna surveys	89

Marine Science

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
Swan	Swan Coastal Plain, Central West Coast	Swan	Access and human use at Penguin Island and related implications for management of Marine Park assets and visitor risk	94
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	93
Pilbara	Pilbara, Ningaloo	Rangelands	Effects of the Gorgon Project dredging program on the marine biodiversity of the Montebello/Barrow Islands marine protected areas	104
Pilbara	Pilbara, Pilbara (Off-shore)	Rangelands	Habitat use, distribution and abundance of coastal dolphin species in the Pilbara	92
Pilbara	Pilbara, (Nearshore)	Pilbara Rangelands	Improving the understanding of West Pilbara marine habitats and associated taxa: their connectivity and recovery potential following natural and human induced disturbance	96
Pilbara	Ningaloo	Rangelands	Interactive effects of fishing and climate change on coral reef fish populations	106
Pilbara	Pilbara, (Nearshore)	Pilbara	Long-term monitoring in the proposed Dampier Archipelago marine reserves	91
Kimberley, Pilbara	Northwest Shelf	Rangelands	North West Shelf Flatback Turtle Conservation Program strategic plan	101
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	101
Warren	WA South Coast	South Coast	Spatial and temporal patterns in benthic invertebrate communities of the Walpole and Nornalup Inlets Marine Park	105
Swan	Central West Coast	Swan	Spatial and temporal patterns in the structure of intertidal reef communities in the marine parks of south-western Australia	107
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	The Western Australian Marine Monitoring Program (WAMMP)	99
Pilbara	Carnarvon, Pilbara (Nearshore)	Pilbara Rangelands	The influence of macroalgal fields on coral reef fish	97
Kimberley	Northern Kimberley, Oceanic Shoals	Rangelands	Understanding movements and identifying important habitats of sea turtles in Western Australia	98

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
Kimberley	Oceanic Shoals, Bonaparte Gulf, Kimberley, Northwest Shelf, Cambridge-Bonaparte, Canning, King Sound, Eighty Mile Beach	Rangelands	WAMSI 2: Kimberley Marine Research Program	102

Ecoinformatics

Parks and Wildlife Region	IBRA/IMCRA	NRM Region	Project Title	Page
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Online GIS biodiversity mapping (<i>NatureMap</i>)	110
All Regions	All IBRA Regions, All IMCRA Regions	All Regions	Provision of authoritative names of Western Australian taxa	109

