Department of Environment and Conservation

Science Division annual research activity report
and management implications
2011–2012




Department of
Environment and Conservation

DIRECTOR'S MESSAGE

Science Division undertakes scientific research for the effective conservation and management of Western Australian biodiversity and to increase knowledge in astronomy. We generate knowledge and understanding of the flora and fauna, the biological communities and landscapes in which they occur, and the ecosystem processes that support them. It is important to take stock periodically to determine how effective we are in achieving our goals. In early 2012 the Science Management Team undertook an evaluation of the outcomes of the science and research undertaken in the Programs and Units of the Division, and identified the strengths, weaknesses and areas for future development as a basis for ongoing strategic planning.

The review of key outcomes demonstrated many significant achievements over the past five years, and significant new directions in the development of marine and climate change research. The Marine Science Program was established in 2006 and has grown substantially from a small base of four staff to a flourishing group of 20 active scientists. A statewide marine monitoring, evaluation and reporting program has been developed to facilitate and promote efficiency and effectiveness of marine protected areas. Research has supported monitoring and management programs with marine baseline information, methodological assessments and evaluation of key pressures and processes. Research into the vulnerability and adaptation of the biota to climate change gained greater focus through the establishment of the Biodiversity and Climate Change Unit in 2008, and we now have six projects specifically addressing climate-related research, along with numerous others that have a climate response component. NatureMap, one of the Division's flagship online data information portals, was launched in 2008 and has flourished to be a comprehensive source of data on Western Australian biodiversity that is widely used to support risk assessment, conservation planning and science-based decisions.

Major biological surveys of the Pilbara IBRA region and selected Kimberley islands have been completed. Results of both surveys are being made available online as papers published in the *Records of the Western Australian Museum Supplement*. Targeted surveys of the Banded Iron Ranges have been undertaken and data are accessible through themed pages in NatureMap. These, and other targeted surveys of terrestrial and aquatic environments, have identified many new species and/or significant range expansions of species, including those that are locally endemic, rare and/or threatened.

The forest monitoring project FORESTCHECK has concluded two rounds of monitoring on a five-year cycle and analysis of the first round of monitoring on 48 grids was published in a special issue of *Australian Forestry* in December 2011. The results of this program have been used in the development of the draft *Forest Management Plan* 2014–2023. Forest stream monitoring has demonstrated little effect of harvesting on stream salinity but has shown that some streams have low invertebrate diversity that is partly attributable to declining rainfall. A major study of forest fire behaviour has resulted in the development of a new fire behaviour prediction model that improves the reliability of predictions across a wide range of fire danger conditions.

Seed conservation and translocation activities have led to achievement of the Target 8 of the Global strategy for Plant Conservation (2002–2010) of 70% (60% target) of the Western Australian threatened flora in *ex-situ* conservation and 13% (10% target) used in translocations. More than 70,000 specimens were added to the Western Australian Herbarium plant specimen collection, and the collection of over 700,000 specimens was moved to new facilities in the Western Australian Conservation Science Centre in 2011. Taxonomic research at the Herbarium has led to the discovery and description of 565 new taxa in the past five years, and over half of these are rare or priority taxa of conservation concern. Integrated genetic and ecological research has identified recommendations for management of small populations and remnant vegetation and design of restoration programs that will facilitate maintenance of species and landscape processes. *Phytophthora* infection is a major threat to flora in the south-west and research has identified novel control and eradication techniques that have been trialed at key sites in the Fitzgerald River National Park.

Restoration of a major rangelands ecosystem is being achieved at Lorna Glen, a former pastoral lease, through removal of domesticated animals, establishment of fire regimes that produce a habitat mosaic and control of introduced predators. Native fauna assemblages are being reconstructed through translocations from Barrow Island and other sites, and from captive breeding facilities. Translocations

of our most threatened mammal, Gilbert's potoroo, to a secure site has led to a significant increase in numbers. Study of interactions between predators has confirmed a mesopredator release, where cats have become significant predators once foxes are reduced in abundance through baiting programs. Eradication of cats and rats is becoming a potential reality with the successful eradication of black rats on Direction Island in the Cocos (Keeling) group.

The Perth Observatory had a significant achievement in being authors on a paper in the prestigious journal *Nature*. The Observatory contributed six years of observations to the analysis that concluded extrasolar planets outnumber stars in the Milky Way Galaxy.

It is a professional obligation of scientists to communicate research findings to a range of audiences, and the reputation of both individual scientists and their institutions is largely built on the quality and quantity of published scientific work. Scientific publications in peer-reviewed journals validate the rigour of the science undertaken in the Division, and communication of the implications of the research to managers and operational staff through technical articles and general publications is also an important means of knowledge transfer. A review of productivity through written communications for the five years from July 2006 to June 2011 identified a significant increase in the rate of scientific publications by staff in the Division. From 2006 to 2011, the Division produced 574 scientific publications (papers, book chapters and books) and 1,376 general publications (conference publications, popular articles, reports, information sheets, etc). This represents an increase of 69% for scientific publications and 86% for general publications compared to the five years from 2001 to 2006. Communication of scientific outcomes and knowledge continues to be a key performance indicator for scientists and the Division to demonstrate effective translation of scientific research into knowledge as a basis for decision making and on-ground management.

The scientific work of the Division that has led to the achievements made over the past five years would not be possible without the efficient support of the administrative staff, the work centre managers and library staff. I thank them for their ongoing dedication to supporting the work of the scientific staff. This year's activity report has been produced through a newly developed online project management system developed by the Science Applications Unit that has greatly increased the efficiency with which the report is produced.

The requirement for scientific information is increasing and, given our finite capacity to meet this challenge, we need to continually review our approach and identify innovative and efficient ways of delivering best-practice science to meet the conservation needs of DEC. The Division has demonstrated many significant achievements over the past five years of which I have only been able to highlight a few. I look forward to ongoing scientific advancements to support biodiversity conservation in Western Australia.

Dr Margaret Byrne

Acting Director

July 2012

CONTENTS

VISION

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

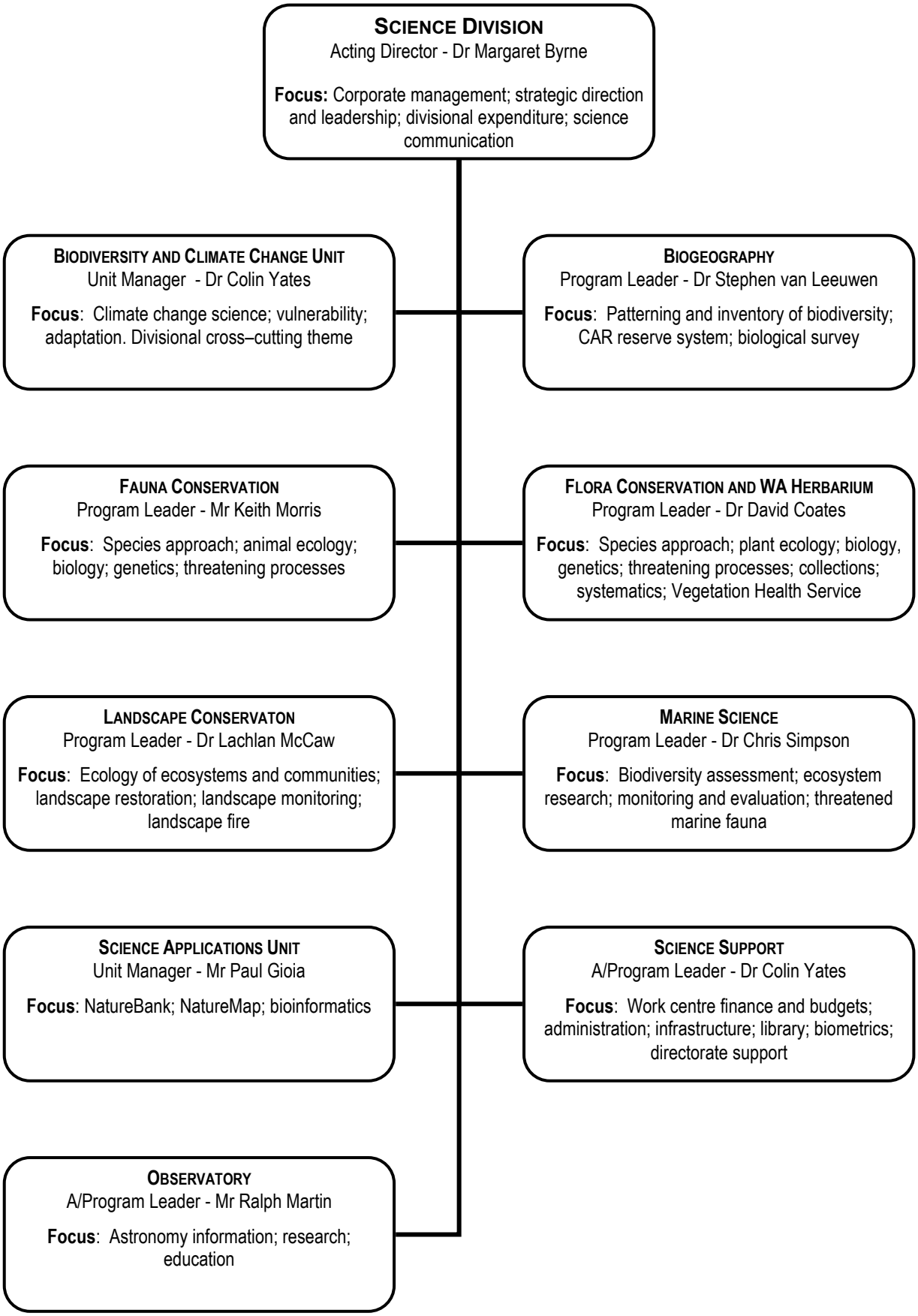
FOCUS AND PURPOSE

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

ROLE

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

SERVICE DELIVERY STRUCTURE



PUBLICATIONS AND REPORTS

Abbott I (2011) Appendix 4: Fauna and ecology in Western Australian exploration, 1836–1845. In *Western Australian Exploration, 1836–1845: the Letters, Reports and Journals of Exploration and Discovery in Western Australia* (eds M Hercock, S Milentis, P Bianchi), pp. 412-418. Hesperian Press, Perth.

Abbott I (2011) Inspecting roots of heritage (BOOK REVIEW). *History West* **50(11)**, p. 7.

Abbott I (2011) Kimberley treasures (BOOK REVIEW). *History West* **50(11)**, p. 7.

Abbott I (2011) Renaming names. *Field Nats News* **210**, p. 4.

Abbott I (2012) Martin Gibbs, The shore whalers of Western Australia: historical archaeology of a maritime frontier, Sydney University Press, 2010, 165 pages (BOOK REVIEW). *History West* **51(1)**, p. 6.

Abbott I, Liddelow GL, Vellios CV, Mellican AE, Williams MR (2011) FORESTCHECK: the response of birds to silviculture in jarrah (*Eucalyptus marginata*) forest. *Australian Forestry* **74**, 328-335.

Abbott I, Williams MR (2011) Silvicultural impacts in jarrah forest of Western Australia: synthesis, evaluation, and policy implications of the FORESTCHECK monitoring project of 2001–06. *Australian Forestry* **74**, 350-360.

Albrecht DE, Hislop M (2011) A revision of *Dielsiodoxa* (Ericaceae: Styphelioideae: Oligarrheneae). *Nuytsia* **21**, 107-126.

Algar D, Angus GJ, Onus ML (2011) Eradication of feral cats on Rottnest Island, Western Australia. *Journal of the Royal Society of Western Australia* **94**, 439-443.

Algar D, Hamilton N, Holdsworth M, Robinson S (2012) Eradicating cats and black rats from Christmas Island. *Landscope* **27(4)**, 43-47.

Algar D, Hamilton N, Onus M (2011) Interim report on Stage 2 of the Management plan for cats and black rats on Christmas Island: report to the Shire of Christmas Island and Christmas Island National Parks. Department of Environment and Conservation, Woodvale, WA.

Algar D, Hilmer S, Nickels D, Nickels AJ (2011) Successful domestic cat neutering: first step towards eradicating cats on Christmas Island for wildlife protection. *Ecological Management and Restoration* **12**, 93-101.

Algar D, Johnston M, Hilmer SS (2011) A pilot study for the proposed eradication of feral cats on Dirk Hartog Island, Western Australia. In *Island Invasives: Eradication and Management* (eds CR Veitch, MN Clout, DR Towns), pp. 10-16. IUCN, Gland.

Algar D, Robertson H, Rummery C (2011) Proposed management plan for baiting feral cats on the Fortescue Marsh: report to the Fortescue Metal Group. Department of Environment and Conservation, Woodvale, WA.

Allen C, Poot P, Moody M, Standish R, Coates D (2011) Back from the brink of extinction: improving the success of endangered plant translocations in south-western Australia (ABSTRACT). In *SER2011: World Conference on Ecological Restoration: Re-establishing the Link Between Nature and Culture: Book of Abstracts, Sunday August 21–Thursday August 25, 2011* p. 12. Conference Organising Committee, Merida, Mexico.

Allen L, Goullet M, Palmer R (2012) The diet of the dingo (*Canis lupus dingo* and hybrids) in north-eastern Australia: a supplement to the paper of Brook and Kutt (2011). *Rangeland Journal* **34**, 211-217.

Bancroft KP, Armstrong S, Ettridge J, Holmes T (2011) Western Australian Marine Monitoring Program: annual marine protected area condition pressure response report: Walpole and Nornalup Inlets Marine Park annual report, 2011. Department of Environment and Conservation, Kensington, WA. 58 p.

Bancroft KP, Campbell R, Cannell B, Friedman KJ, Holmes T, Kendrick A et al. [Rule M, Waples K] (2011) Western Australian Marine Monitoring Program: annual marine protected area condition pressure response report: Shoalwater Islands Marine Park annual report, 2011. Department of Environment and Conservation, Kensington, WA. 103 p.

Bancroft KP, Campbell R, Dasey M, Friedman KJ, Holmes T, Rule MJ et al. [Waples K] (2011) Western Australian Marine Monitoring Program: annual marine protected area condition pressure response report: Jurien Bay Marine Park annual report, 2011. Department of Environment and Conservation, Kensington, WA. 67 p.

Bancroft KP, Campbell R, Friedman KJ, Holmes T, Kendrick A, Lierich D et al. [Rule M, Waples K] (2011) Western Australian Marine Monitoring Program: annual marine protected area condition pressure response report: Marmion Marine Park annual report, 2011. Department of Environment and Conservation, Kensington, WA. 90 p.

Bancroft KP, Coutts T, Friedman KJ, Holmes T, Moore JAY, Waples K (2011) Western Australian Marine Monitoring Program: annual marine protected area condition pressure response report: Rowley Shoals Marine Park annual report, 2011. Department of Environment and Conservation, Kensington, WA. 58 p.

Bancroft KP, Evans R, Field S, Friedman KJ, Holmes T, Middlebrook R et al. [Moore JAY, Rule MJ, Shedrawi G, Waples K, Whiting S] (2011) Western Australian Marine Monitoring Program: annual marine protected area condition pressure response report: Montebello Islands Marine Park, Barrow Island Marine Park and Barrow Islands Marine Management Area annual report, 2011. Department of Environment and Conservation, Kensington, WA. 104 p.

Bancroft KP, Friedman KJ, Holley D, Holmes T, Moore JAY, Murray K et al. [Rule MJ, Waples K, Whiting S] (2011) Western Australian Marine Monitoring Program: annual marine protected area condition pressure response report: Shark Bay Marine Park and Hamelin Pool Marine Nature Reserve annual report, 2011. Department of Environment and Conservation, Kensington, WA. 97 p.

Bancroft KP, Holmes T, Moore JAY, Murray K, Rule MJ, Taylor H et al. [Wilson S, Waples K, Whiting S] (2011) Western Australian Marine Monitoring Program: annual marine protected area condition pressure response report: Ningaloo Marine Park and Muiron Islands Marine Management Area annual report, 2011. Department of Environment and Conservation, Kensington, WA. 91 p.

Bancroft KP, Lierich D (2011) Western Australian Marine Monitoring Program: annual marine protected area condition pressure response report: Swan Estuary Marine Park annual report, 2011. Department of Environment and Conservation, Kensington, WA. 15 p.

Barrett S, Dillon R, Cochrane A, Monks L (2011) Conservation introduction of a threatened narrow range endemic species, *Banksia montana*, from the Stirling

Range National Park, southern Western Australia. In *Global Re-introduction Perspectives 2011: More Case Studies From Around the World* (ed PS Soorae), pp. 220-223. IUCN, Gland.

Bencini R, Mills H, Chambers B, de Tores P, Harris I, Yokochi K (2011) Fauna crossings down under: who is using them and why? (ABSTRACT). *Australian Mammal Society Newsletter* **Oct**, 32-33.

Berry O, Algar D, Angus J, Hamilton N, Hilmer S, Sutherland D (2012) Genetic tagging reveals a significant impact of poison baiting on an invasive species. *Journal of Wildlife Management* **76**, 729-739.

Biggs JD, Fouche T, Bilki F, Zadnik M (2012) Measuring and mapping the night sky brightness of Perth, Western Australia. *Monthly Notices of the Royal Astronomical Society* **421**, 1450-1464.

Bishop CL, Williams MR, Wardell-Johnson GW (2011) A forest pathogen drives change in plant functional trait composition in the southwest Australian floristic region. *Agriculture, Ecosystems and Environment* **145**, 59-66.

Bode M, Brennan KEC, Morris K, Burrows N, Hague N (2012) Choosing cost-effective locations for conservation fences in the local landscape. *Wildlife Research* **39**, 192-201.

Boer MM, Sadler RJ, Wittkuhn R, McCaw L, Grierson PF (2011) Quantifying the effectiveness of fuel management in modifying wildfire behaviour: recent examples from Western Australia and Victoria (ABSTRACT). In *Western Australian Bushfire Research Forum 2011, 12 and 13 October 2011: Book of Abstracts* p. 29. Department of Environment and Conservation, Kensington, WA.

Bougher N (2011) Fungi-fauna linkages in Western Australia: potoroos and beetles (ABSTRACT). In *Fungimap VI: 14–19 July 2011, Denmark, Western Australia* p. 7. Conference Organising Committee, Denmark.

Bougher NL (2011) Fungi of Perth's Banksia woodlands. In *Perth's Banksia Woodlands: Precious and Under Threat. Proceedings of a Symposium on the Ecology of These Ancient Woodlands and Their Need for Protection from Neglect and Destruction, 25 March 2011, Wollaston College Conference Centre, Mount Claremont* pp. 11-14. Urban Bushland Council, West Perth.

Bougher NL (2011) Fungi survey: Bold Park 2011. Department of Environment and Conservation, Kensington, WA. 19 p.

Bougher NL (2011) Fungi survey: Kings Park and Botanic Garden 2011. Department of Environment and Conservation, Kensington, WA. 17 p.

Bougher NL (2011) New records of fungi and slime moulds at Kings Park, Perth, Western Australia. *Western Australian Naturalist* **28**, 24-42.

Bougher N, Matheny B, Ryberg M (2011) Getting to know the *Inocybe* family of fungi in Australia (ABSTRACT). In *Fungimap VI: 14–19 July 2011, Denmark, Western Australia* p. 15. Conference Organising Committee, Denmark.

Bougher N, Matheny P (2011) New project to discover the fibre-head fungi in Australia. *Naturalist News* **Nov**, p. 7.

Bougher NL, Matheny PB (2011) Two species of *Inocybe* (fungi) introduced into Western Australia. *Nuytsia* **21**, 139-148.

Bougher NL, Matheny PB, Gates GM (2012) Five new species and records of *Inocybe* (Agaricales) from temperate and tropical Australia. *Nuytsia* **22**, 57-74.

Bragg TB, Ward BG (2011) Post fire plant succession and biodiversity in the Gibson Desert of Western Australia (ABSTRACT). In *Western Australian Bushfire Research Forum 2011, 12 and 13 October 2011: Book of Abstracts* pp. 14–15. Department of Environment and Conservation, Kensington, WA.

Brennan KEC, Twigg PJ, Watson A, Pennington A, Sumner J, Davis R et al. [Jackson J] (2012) Cross-cultural systematic biological surveys in Australia‘s Western Desert. *Ecological Management and Restoration* **13**, 72-80.

Brewer TD, Cinner JE, Fisher R, Green A, Wilson SK (2012) Market access, population density, and socioeconomic development explain diversity and functional group biomass of coral reef fish assemblages. *Global Environmental Change* **22**, 399-406.

Bryce C, Sampey A, Fromont J, Morrison S, Marsh L, Hosie A et al. [Huisman J] (2011) Marine life of the Kimberley bioregion: past, present and future (ABSTRACT). In *Australian Marine Sciences Association, 48th Annual Conference, 3rd–7th July 2011: Book of Abstracts* p. 30. Conference Organising Committee, Fremantle.

Bullen RD, McKenzie NL (2011) Recent developments in studies of the community structure, foraging ecology and conservation of Western Australian bats. In *The Biology and Conservation of Australasian Bats* (eds B Law, P Eby, D Lunney et al.), pp. 31-43. Royal Zoological Society of New South Wales, Mosman.

Bullen RD, McKenzie NL (2012) Quasi-steady aerodynamic model for bat airframes. Model vers 1.1. Available at: http://www.dec.wa.gov.au/content/view/6918/1813/ Department of Environment and Conservation, Woodvale, WA. 13 p.

Burbidge AA, Abbott I, Comer S, Adams E, Berry O, Penwarden KE (2011) Unforeseen consequences of a misidentified rodent: case study from the Archipelago of the Recherche, Western Australia. *Australian Mammalogy* **34**, 55-58.

Burbidge AA, Byrne M, Coates D, Garnett ST, Harris S, Hayward MW et al. (2011) Is Australia ready for assisted colonisation? Policy changes required to facilitate translocations under climate change (ABSTRACT). In *ICCB 2011: Engaging Society in Conservation: Abstracts: 25th International Congress for Conservation Biology: Auckland, New Zealand, 5–9 December 2011* p. 20. Society for Conservation Biology, Auckland.

Burbidge AA, Byrne M, Coates D, Garnett ST, Harris S, Hayward MW et al. (2011) Is Australia ready for assisted colonization? Policy changes required to facilitate translocations under climate change. *Pacific Conservation Biology* **17**, 259-269.

Burbidge AA, Morris KD (2012) Analysis of spotlighting data from Barrow Island Nature Reserve, Western Australia. Department of Environment and Conservation, Woodvale, WA. 12 p.

Burbidge A (2011) The Duke and the scrub-bird. *Western Australian Bird Notes* **140**, p. 14.

Burbidge A (2012) Potential suitability of the Turee Creek Flats, Karijini National Park, for night parrots. Department of Environment and Conservation, Woodvale, WA. 7 p.

Burrows N (2011) Managing fire in the Western Desert: what can 40,000 years of human occupation teach us? (ABSTRACT). In *Western Australian Bushfire Research Forum 2011, 12 and 13 October 2011: Book of*

Abstracts p. 13. Department of Environment and Conservation, Kensington, WA.

Burrows N (2011) Mosaic burning in south-west forest ecosystems for biodiversity and community protection (ABSTRACT). In *Western Australian Bushfire Research Forum 2011, 12 and 13 October 2011: Book of Abstracts* p. 19. Department of Environment and Conservation, Kensington, WA.

Burrows ND (2012) Notes on a bushfire on Wagga Wagga Station, Yalgoo Shire. Department of Environment and Conservation, Kensington, WA. 8 p.

Burrows N, Foster C, Foster J, Fowler T, Gilbert C, Hanley K et al. (2012) Monitoring bilby (*Macrotis lagotis*) and other animal activity at Lorna Glen using observers on horseback. Department of Environment and Conservation, Kensington, WA. 19 p.

Burrows N, Hearle G, Woods T, Liddelow G (2011) Lorna Glen introduced predator monitoring: 22–26 July 2011, post-bait data summary. Department of Environment and Conservation, Kensington, WA. 6 p.

Burrows N, Ward B (2012) Lorna Glen introduced predator monitoring, 27–31 January 2012. Department of Environment and Conservation, Kensington, WA. 6 p.

Butcher R (2012) *Tephrosia bidwillii* (Fabaceae: Millettieae) does not occur in Western Australia. *Nuytsia* **22**, 41-42.

Butcher R (2012) Three new species allied to the *Mirbelia viminalis* group (Fabaceae: Mirbelieae), from Western Australia. *Nuytsia* **22**, 75-92.

Butcher R, Byrne M, Crayn D (2011) So near yet so far: evolutionary relationships among rare *Tetratheca* species endemic to banded ironstone ranges in Western Australia (POSTER ABSTRACT). In *IBC2011, XVIII International Botanical Congress: Melbourne, Australia, 23–30 July 2011, Melbourne Congress and Exhibition Centre, Nomenclature Section, 17–22 July, 2011, University of Melbourne: Abstract Book* p. 368.

Byrne M (2011) Genetic diversity and mating systems in eucalypt evolution (ABSTRACT). In *IBC2011, XVIII International Botanical Congress: Melbourne, Australia, 23–30 July 2011, Melbourne Congress and Exhibition Centre, Nomenclature Section, 17–22 July, 2011, University of Melbourne: Abstract Book* p. 319.

Byrne M (2012) Future Farm Industries CRC Ltd, project annual report, 1 July 2011–30 June 2012: P4 DP26, Weed & genetic risk 2. Department of Environment and Conservation, Kensington, WA. 7 p.

Byrne M, Coates DJ, Millar MA (2011) Assessing patterns of genetic diversity: essential data for implementing plant reintroduction strategies (ABSTRACT). In *ICCB 2011: Engaging Society in Conservation: Abstracts: 25th International Congress for Conservation Biology: Auckland, New Zealand, 5–9 December 2011* p. 22. Society for Conservation Biology, Auckland.

Byrne M, Prober S, Stock W, Potts B, Vaillancourt R (2012) Climate Change Adaptation Research Grants Program progress report: Climate-resilient vegetation of multi-use landscapes: exploiting genetic variability in widespread species. Department of Environment and Conservation, Kensington, WA. 4 p.

Byrne M, Steane DA, Joseph L, Yeates DK, Jordan GJ, Crayn D et al. (2011) Decline of a biome: evolution, contraction, fragmentation, extinction and invasion of the Australian mesic zone biota. *Journal of Biogeography* **38**, 1635-1656.

Byrne M, Stone L, Millar MA (2011) Assessing genetic risk in revegetation. *Journal of Applied Ecology* **48**, 1365-1373.

Byrne M, Yates C, Coates D, Elliott C, Gibson N, Sampson J et al. [Millar M] (2011) Restoring and maintaining genetic connections in a landscape context (ABSTRACT). In *Genetics Society of AustralAsia, Annual Conference 2011: Melbourne, July 10–13th 2011* p. 103. Conference Organising Committee, Melbourne.

Cale DJ, McCormick C, Lyons MN, Pinder AM (2011) State Salinity Strategy wetland biodiversity monitoring report: Lake Wheatfield 1997–2009. Department of Environment and Conservation, Woodvale, WA. 64 p.

Campbell KJ, Harper G, Algar D, Hanson CC, Keitt BS, Robinson S (2011) A updated review of feral cat eradications on islands. In *Island Invasives: Eradication and Management* (eds CR Veitch, MN Clout, DR Towns), pp. 37-46. IUCN, Gland.

Campbell R (2011) The long road to recovery. *Landscope* **27(2)**, 10-15.

Cassan A, Kubas D, Beaulieu J-P, Dominik M, Horne K, Greenhill J et al. [Williams A, Martin R] (2012) One or more bound planets per Milky Way star from microlensing observations. *Nature* **481**, 167-169.

Chambers J, Wilson C, Tulbure M et al. [Clarke A] (2011) Investigation of nutrient thresholds for ecological regime change in the Vasse–Wonnerup estuary in south-western Australia (ABSTRACT). In *Australian Marine Sciences Association, 48th Annual Conference, 3rd–7th July 2011: Book of Abstracts* p. 37. Conference Organising Committee, Fremantle.

Chapman T (2011) Application of digital photogrammetry to measure a cast of an animal excavation. Available at: http://www.dec.wa.gov.au/component/option,com_docman/task,doc_download/gid,6235/Itemid,/ Department of Environment and Conservation, Western Australia, Science Division, Information Sheet **42**, DEC, Kensington, WA. 2 p.

Cheney NP, Gould JS, McCaw WL, Anderson WR (2012) Predicting fire behaviour in dry eucalypt forest in southern Australia. *Forest Ecology and Management* **280**, 120-131.

Choi J-Y, Shin I-G, Park S-Y, Han C, Gould A, Sumi T et al. [Williams A] (2012) Characterizing lenses and lensed stars of high-magnification single-lens gravitational microlensing events with lenses passing over source stars. *Astrophysical Journal* **751**, 1-14.

Clarke LJ, Jardine DI, Byrne M, Shepherd K, Lowe AJ (2012) Significant population genetic structure detected for a new and highly restricted species of *Atriplex* (Chenopodiaceae) from Western Australia, and implications for conservation management. *Australian Journal of Botany* **60**, 32-41.

Coates D (2011) The future of plant diversity (ABSTRACT). In *IBC2011, XVIII International Botanical Congress: Melbourne, Australia, 23–30 July 2011, Melbourne Congress and Exhibition Centre, Nomenclature Section, 17–22 July, 2011, University of Melbourne: Abstract Book* p. 13.

Coates DJ, Byrne M, Brown A (2011) Augmented gene flow for plant population persistence in a highly fragmented landscape (ABSTRACT). In *ICCB 2011: Engaging Society in Conservation: Abstracts: 25th International Congress for Conservation Biology: Auckland, New Zealand, 5–9 December 2011* p. 30. Society for Conservation Biology, Auckland.

Coates D, Byrne M, van Leeuwen S (2012) Genetic diversity in *Aluta quadrata*: implications for provenance seed collections and management. Department of Environment and Conservation, Kensington, WA. 12 p.

Cochrane A (2011) Climate warming and the germination niche. *Australasian Plant Conservation* **19(3)**, 6-8.

Cochrane A (2011) The relevance of germination requirements to assisted migration under a changing climate (ABSTRACT). *In: Ecological Society of Australia, 2011 Annual Conference: Ecology in Changing Landscapes: Conference Handbook, 21–25 November, 2011, Wrest Point, Hobart, Tasmania* p. 191. Conference Organising Committee, Hobart.

Cochrane A, Daws MI, Hay FR (2011) A seed-based approach for identifying flora at risk from climate warming. *Austral Ecology* **36**, 923-935.

Cole AJ, Lawton RJ, Wilson SK, Pratchett MS (2012) Consumption of tabular acroporid corals by reef fishes: a comparison with plant-herbivore interactions. *Functional Ecology* **26**, 307-316.

Collins S, McComb JA, Howard K, Shearer BL, Colquhoun IJ, Hardy GESJ (2012) The long-term survival of *Phytophthora cinnamomi* in mature *Banksia grandis* killed by the pathogen. *Forest Pathology* **42**, 28-36.

Comer S, Tiller C, Danks A, Burbidge A (2011) Translocations of the endangered noisy scrub-bird as a mechanism for increasing resilience in changing climates (ABSTRACT). *In: Ecological Society of Australia, 2011 Annual Conference: Ecology in Changing Landscapes: Conference Handbook, 21–25 November, 2011, Wrest Point, Hobart, Tasmania* p. 112. Conference Organising Committee, Hobart.

Cowan M (2011) Vertebrate survey in Cane River Conservation Park with a focus on the Nanutarra Block: Cane River Conservation Park, Western Australia, 20th June–1st July 2011. Department of Environment and Conservation, Kensington, WA. 24 p.

Cowan M, Harris D, Ho K, Whitehead T (2011) Development of ethically-acceptable techniques for invertebrate wet pit trapping: summary report for DEC Science Division. ChemCentre, Perth. 28 p.

Cowan MA, Parkin T (2012) Vertebrate survey of Credo Station: Credo Station, Goldfields Region, Western Australia, 29th August–9th September 2011. Department of Environment and Conservation, Woodvale, WA. 30 p.

Cranfield R (2011) An introduction to lichens for beginners (ABSTRACT). In *Fungimap VI: 14–19 July 2011, Denmark, Western Australia* p. 14. Conference Organising Committee, Denmark.

Cranfield R (2012) Avon wheatbelt lichens. *Landscope* **27(4)**, 56-61.

Cranfield RJ, Robinson RM, Williams MR, Tunsell VL (2011) FORESTCHECK: the response of lichen and bryophytes to silviculture in jarrah (*Eucalyptus marginata*) forest. *Australian Forestry* **74**, 303-314.

Crous PW, Groenewald JZ, Shivas RG, Edwards J, Seifert KA, Alfenas AC et al. [Stukely MJC] (2011) Fungal Planet description sheets, 69–91. *Persoonia* **26**, 108-156.

Crous PW, Summerell BA, Shivas RG, Burgess TI, Decock CA, Dreyer LL et al. [Stukely MJC] (2012) Fungal Planet description sheets, 107–127. *Persoonia* **28**, 138-182.

Danks A, Comer S, Burbidge A (2011) Back from the brink: 50 years of conservation at Two Peoples Bay. *Landscope* **27(1)**, 32-38.

Davis RW (2011) An assessment of some infraspecific taxa in *Ptilotus* (Amaranthaceae) from Western Australia. *Nuytsia* **21**, 103-106.

Davis RW (2011) Re-evaluation of some infraspecific taxa in *Ptilotus* (Amaranthaceae). *Nuytsia* **21**, 149-151.

Davis RW (2012) *Ptilotus exiliflorus*, a new name for *Ptilotus parviflorus* (Benth.) R.W.Davis (Amaranthaceae). *Nuytsia* **22**, p. 43.

Davis RW, Tauss C (2011) A new and rare species of *Ptilotus* (Amaranthaceae) from a suburban wetland of the eastern Swan Coastal Plain, Western Australia. *Nuytsia* **21**, 97-102.

Davison EM (2011) *Amanita ochroterrea* and *Amanita brunneiphylla* (Basidiomycota), one species or two? *Nuytsia* **21**, 177-184.

Daw B, Walley T, Keighery G (2011) *Bush Tucker Plants of the South-West*. Department of Environment and Conservation, Kensington, WA. 64 p.

Daw TM, Cinner JE, McClanahan TR, Graham NAJ, Wilson SK (2011) Design factors and socioeconomic variables associated with ecological responses to fishery closures in the Western Indian Ocean. *Coastal Management* **39**, 412-424.

De Tores PJ, Marlow N (2012) The relative merits of predator-exclusion fencing and repeated fox baiting for protection of native fauna: five case studies from Western Australia. In *Fencing for Conservation: Restriction of Evolutionary Potential or a Riposte to Threatening Processes?* (eds MJ Somers, MW Hayward), pp. 21-42. Springer, New York.

Dillon R, Barrett S, Cochrane A, Monks L (2011) Conservation introductions and range movements of threatened species in southern Western Australia (ABSTRACT). *In: Ecological Society of Australia, 2011 Annual Conference: Ecology in Changing Landscapes: Conference Handbook, 21–25 November, 2011, Wrest Point, Hobart, Tasmania* p. 97. Conference Organising Committee, Hobart.

Doughty P, Rolfe JK, Burbidge AH, Pearson DJ, Kendrick PG (2011) Herpetological assemblages of the Pilbara biogeographic region, Western Australia: ecological associations, biogeographic patterns and conservation. *Records of the Western Australian Museum. Supplement* **78**, 315-341.

Dunne CP, Crane CE, Lee M, Massenbauer T, Barrett S, Comer S et al. [Freebury GJC, Utber DJ, Grant MJ, Shearer BL] (2011) A review of the catchment approach techniques used to manage a *Phytophthora cinnamomi* infestation of native plant communities of the Fitzgerald River National Park on the south coast of Western Australia. *New Zealand Journal of Forestry Science* **41S**, S121-S132.

Durrant B (2011) Short-range endemism in the central Pilbara: final report, 7th September 2011. Department of Environment and Conservation, Woodvale, WA. 33 p.

Elith J, Phillips SJ, Hastie T, Dudik M, Chee YE, Yates CJ (2011) A statistical explanation of MaxEnt for ecologists. *Diversity and Distributions* **17**, 43-57.

Ellis R (2011) Out come the wolves: wolf spiders. *Landscope* **27(2)**, 18-25.

Eshraghi L, Anderson J, Aryamanesh N, Shearer B, McComb J, Hardy GES et al. (2011) Phosphite primed defence responses and enhanced expression of defence genes in *Arabidopsis thaliana* infected with *Phytophthora cinnamomi*. *Plant Pathology* **60**, 1086-1095.

Eshraghi L, Aryamanesh N, Anderson JP, Shearer B, McComb JA, Hardy GESJ et al. (2011) A quantitative PCR assay for accurate *in planta* quantification of the necrotrophic pathogen *Phytophthora cinnamomi*. *European Journal of Plant Pathology* **131**, 419-430.

Evans R, Murray K, Shedrawi G, Field S (2011) Digitise this! A quick and easy remote sensing method to monitor the daily extent of dredge plumes

(ABSTRACT). In *Australian Marine Sciences Association, 48th Annual Conference, 3rd–7th July 2011: Book of Abstracts* p. 182. Conference Organising Committee, Fremantle.

Farr J, Wills A (2011) Gumleaf skeletonizer (GLS) and Desire: field testing the New Zealand sex pheromone lure system during a recent outbreak of GLS (*Uraba lugens*) in south-west Western Australia (ABSTRACT). In *3rd Combined Australian and New Zealand Entomological Societies Conference: 28 August–1 September 2011, Lincoln University, Christchurch, New Zealand* p. 68. Conference Organising Committee, Christchurch.

Farr J, Wills A (2012) Gumleaf skeletonizer (*Uraba lugens*) outbreak, February 2010: preliminary survey of the extent and severity of gumleaf skeletonizer outbreak in Warren region, February 2010. Department of Environment and Conservation, Kensington, WA. 11 p.

Farr JD, Wills AJ, van Heurck PF, Mellican AE, Williams MR (2011) FORESTCHECK: the response of macro-invertebrates to silviculture in jarrah (*Eucalyptus marginata*) forest. *Australian Forestry* **74**, 315-327.

Field S, Shedrawi G, Evans R (2011) Effects of the Gorgon dredging program on selected aspects of the marine biodiversity of the Montebello Barrow Island MPA's (ABSTRACT). In *Australian Marine Sciences Association, 48th Annual Conference, 3rd–7th July 2011: Book of Abstracts* p. 58. Conference Organising Committee, Fremantle.

Fordham DA, Akçakaya HR, Araújo MB, Elith J, Keith DA, Pearson R et al. [Yates C] (2012) Plant extinction risk under climate change: are forecast range shifts alone a good indicator of species vulnerability to global warming? *Global Change Biology* **18**, 1357-1371.

Frank A, Johnson C, Fisher A, Legge S, Lawes M, Collis M-A et al. [Radford I] (2011) Are cats causing northern Australian mammal declines? Tackling the challenge of monitoring a cryptic predator (ABSTRACT). *In: Ecological Society of Australia, 2011 Annual Conference: Ecology in Changing Landscapes: Conference Handbook, 21–25 November, 2011, Wrest Point, Hobart, Tasmania* p. 66. Conference Organising Committee, Hobart.

Frank A, Johnson C, Fisher A, Legge S, Lawes M, Collis M-A et al. [Radford I] (2011) Will reptiles experience the same declines as small mammals in the top end? (POSTER ABSTRACT). *In: Ecological Society of Australia, 2011 Annual Conference: Ecology in Changing Landscapes: Conference Handbook, 21–25 November, 2011, Wrest Point, Hobart, Tasmania* p. 255. Conference Organising Committee, Hobart.

Friedman K (2011) WAMMP: monitoring strategies for active adaptive conservation management of marine biodiversity in Western Australia (ABSTRACT). In *Australian Marine Sciences Association, 48th Annual Conference, 3rd–7th July 2011: Book of Abstracts* p. 61. Conference Organising Committee, Fremantle.

Friedman K, Eriksson H, Tardy E, Pakoa K (2011) Management of sea cucumber stocks: patterns of vulnerability and recovery of sea cucumber stocks impacted by fishing. *Fish and Fisheries* **12**, 75-93.

Friedman K, Golbuu Y (2011) Palau. In *Marine Protected Areas: Country Case Studies on Policy, Governance and Institutional Issues* (comps JS Sanders, D Gréboval, A Hjort), pp. 50-71. FAO, Rome.

Friend JA (2011) Is Gilbert's potoroo still the world's rarest marsupial (ABSTRACT). *Australian Mammal Society Newsletter* **Oct**, p. 63.

Friend JA, Comer S (2012) Bald Island, South Coast Region, Western Australia: a threatened species haven can become a breeding colony (ABSTRACT). In *Island Arks Symposium II: 7–9th February 2012, University House, Canberra* 62-63. Conference Organising Committee, Canberra.

Gibson LA (2012) Island treasures: biodiversity assets of the islands along the Kimberley coast of West Australia (ABSTRACT). In *Island Arks Symposium II: 7–9th February 2012, University House, Canberra* p. 53. Conference Organising Committee, Canberra.

Gibson L, Köhler F (2011) Island treasures: patterns of species diversity and composition of land snails on Kimberley islands (ABSTRACT). *In: Ecological Society of Australia, 2011 Annual Conference: Ecology in Changing Landscapes: Conference Handbook, 21–25 November, 2011, Wrest Point, Hobart, Tasmania* p. 238. Conference Organising Committee, Hobart.

Gibson LA, Köhler F (2012) Determinants of species richness and similarity of species composition of land snail communities on Kimberley islands. *Records of the Western Australian Museum, Supplement* **81**, 40-65.

Gibson LA, McKenzie NL (2012) Identification of biodiversity assets on selected Kimberley islands: background and implementation. *Records of the Western Australian Museum, Supplement* **81**, 1-14.

Gibson LA, McKenzie NL (2012) Occurrence of non-volant mammals on islands along the Kimberley coast of Western Australia. *Records of the Western Australian Museum, Supplement* **81**, 15-39.

Gibson MR, Richardson DM, Marchante E, Marchante H, Rodger JG, Stone GN et al. [Byrne M] (2011) Reproductive biology of Australian acacias: important mediator of invasiveness? *Diversity and Distributions* **17**, 911-933.

Gibson N (2011) *Labichea rossii* (Fabaceae: Caesalpinioideae), a new species from the Yilgarn Ranges, Western Australia. *Nuytsia* **21**, 91-95.

Gibson N, Langley MA (2012) Vascular flora of Credo Station and adjacent reserves: a report to the Bush Blitz Program, Australian Biological Resources Study. Department of Environment and Conservation, Kensington, WA. 30 p.

Gioia P (2011) The native garden: reconnecting home and place. *Landscope* **27(1)**, 48-51.

Gosper CR (2011) Birds of the northern Great Victoria Desert: the 2010 Sykes Bluff desert discovery project. *Western Australian Bird Notes* **139**, 2-9.

Gosper CR (2012) Birds of two important bird areas of Western Australia: Lake Magenta and Dunn Rock & Lake King. *Australian Field Ornithology* **29**, 1-14.

Gosper CR, Prober SM, Yates CJ (2011) Fire ecology studies in the world's largest Mediterranean-climate woodland (ABSTRACT). In *MEDECOS XII: Linking Science to Resource Management: the International Mediterranean Ecosystems Conference: September 6–9, 2011, Los Angeles, California, United States: Abstracts* p. 73. Conference Organising Committee, Los Angeles.

Gosper CR, Prober SM, Yates CJ (2011) Responses to fire of Mediterranean-climate shrublands in southwestern Australia (ABSTRACT). In *MEDECOS XII: Linking Science to Resource Management: the International Mediterranean Ecosystems Conference: September 6–9, 2011, Los Angeles, California, United States: Abstracts* p. 74. Conference Organising Committee, Los Angeles.

Gosper CR, Yates CJ, Prober SM (2011) Effects of the fire management method of chaining and burning on plant communities (ABSTRACT). In *Western Australian Bushfire Research Forum 2011, 12 and 13 October*

2011: Book of Abstracts p. 36. Department of Environment and Conservation, Kensington, WA.

Gosper CR, Yates CJ, Prober SM, Parsons BC (2012) Contrasting changes in vegetation structure and diversity with time since fire in two Australian Mediterranean-climate plant communities. *Austral Ecology* **37**, 164-174.

Gustafsson L, Baker SC, Bauhus J, Beese WJ, Brodie A, Kouki J et al. [Wayne A] (2012) Retention forestry to maintain multifunctional forests: a world perspective. *Bioscience* **62**, 633-645.

Guthrie NA (2012) Coleopteran fauna survey of Credo Station, Goldfields region, Western Australia, 29th August–9th September 2011. Department of Environment and Conservation, Woodvale, WA. 18 p.

Guthrie NA, Hilmer SS, Algar D, Richards JD (2011) A survey of ground-dwelling invertebrates from Mount Gibson Wildlife Sanctuary and Karara–Lochada pastoral stations. *Conservation Science Western Australia* **8**, 23-29.

Harrison HB, Williamson DH, Evans RD, Almany GR, Thorrold SR, Russ GR et al. (2012) Larval export from marine reserves and the recruitment benefit for fish and fisheries. *Current Biology* **22**, 1023-1028.

Hislop M (2011) New, locally endemic taxa in *Leucopogon* (Ericaceae: Styphelioideae: Styphelieae) from the Perth and midwest regions of Western Australia. *Nuytsia* **21**, 75-89.

Hislop M (2011) A reinstatement and a new combination in *Leucopogon* (Ericaceae: Styphelioideae: Styphelieae). *Nuytsia* **21**, 163-176.

Hislop M (2012) *Leucopogon navicularis* (Ericaceae: Styphelioideae: Styphelieae), another local endemic from the midwest region of Western Australia. *Nuytsia* **22**, 45-50.

Hislop M (2012) Two new species from the *Leucopogon distans* group (Ericaceae: Styphelioideae: Styphelieae) and the reinstatement of *L. penicillatus*. *Nuytsia* **22**, 1-16.

Hislop M, Lepschi BJ, Craven LA (2011) *Melaleuca marginata*, a new name for *Melaleuca coronicarpa* (Myrtaceae). *Nuytsia* **21**, 153-154.

Hislop M, Puente-Lelievre C, Crayn D (2012) *Leucopogon extremus* (Styphelieae, Styphelioideae, Ericaceae), a remarkable new species that expands the morphological circumscription of *Leucopogon* sens. str. *Australian Systematic Botany* **25**, 202-209.

Hollister C, Lander N, Thiele K, Butcher R (2011) Keys to the Proteaceae of Western Australia. Department of Environment and Conservation, Kensington, WA. 1 CD-ROM.

Hollister C, Thiele K (2012) Keys to the Goodeniaceae of Western Australia. Department of Environment and Conservation, Kensington, WA. 1 CD-ROM.

Holmes T, Friedman K, Bancroft K, Field S (2011) WAMMP, fish and coral surveys of the Rowley Shoals, 2011. Meta Data Report **MDR_FishCoral_RSMP_201109**, Department of Environment and Conservation, Kensington, WA. 59 p.

Hui C, Richardson DM, Robertson MP, Wilson JRU, Yates CJ (2011) Macroecology meets invasion ecology: linking the native distributions of Australian acacias to invasiveness. *Diversity and Distributions* **17**, 872-883.

Huisman J (2011) The last frontier: the marine benthic flora of north-western Australia (ABSTRACT). In *IBC2011, XVIII International Botanical Congress: Melbourne, Australia, 23–30 July 2011, Melbourne Congress and Exhibition Centre, Nomenclature Section, 17–22 July, 2011, University of Melbourne: Abstract Book* p. 203.

Huisman JM (2012) Illogical etymology and the curious case of *Ceramium*. *Taxon* **61**, 456-458.

Hurter J, Naaykens J (2012) Report on a follow up visit to Kilto Station to investigate the invasiveness of *Chloris gayana* after good summer rain. Department of Environment and Conservation, Kensington, WA. 6 p.

Iles WJD, Rudall PJ, Sokoloff DD, Remizowa MV, Macfarlane TD, Logacheva MD et al. (2012) Molecular phylogenetics of Hydatellaceae (Nymphaeales): sexual-system homoplasy and a new sectional classification. *American Journal of Botany* **99**, 663-676.

Jabaily RS, Shepherd KA, Gustafsson MHG, Sage LW, Krauss SL, Howarth DG et al. (2012) Systematics of the Austral-Pacific family Goodeniaceae: establishing a taxonomic and evolutionary framework. *Taxon* **61**, 419-436.

Johnson B, Morris K (2011) Eradication of exotic rodents off six high conservation value Western Australian islands (ABSTRACT). In *Island Invasives: Eradication and Management: Proceedings of the International Conference on Island Invasives* (eds CR Veitch, MN Clout, DR Towns), p. 527. IUCN, Gland.

Johnston M, Algar D, O'Donoghue M, Morris J (2011) Field efficacy of the Curiosity feral cat bait on three Australian islands. In *Island Invasives: Eradication and Management* (eds CR Veitch, MN Clout, DR Towns), pp. 182-187. IUCN, Gland.

Joseph L, Burbidge A, Murphy S (2012) Night parrot, *Pezoporus occidentalis* (Gould, 1861). In *Queensland's Threatened Animals* (eds LK Curtis, AJ Dennis, KR McDonald et al.), pp. 300-301. CSIRO Publishing, Collingwood.

Kaewmongkol G, Kaewmongkol S, Burmej H, Bennett MD, Fleming PA et al. [Wayne AF] (2011) Diversity of *Bartonella* species detected in arthropod vectors from animals in Australia. *Comparative Immunology, Microbiology and Infectious Diseases* **34**, 411-417.

Keesing JK, Irvine TR, Alderslade P, Clapin G, Fromont J, Hosie AM et al. [Huisman JM] (2011) Marine benthic flora and fauna of Gourdon Bay and the Dampier Peninsula in the Kimberley region of north-western Australia. *Journal of the Royal Society of Western Australia* **94**, 285-301.

Keighery G (2011) Banksia woodlands: a Perth icon. In *Perth's Banksia Woodlands: Precious and Under Threat. Proceedings of a Symposium on the Ecology of These Ancient Woodlands and Their Need for Protection from Neglect and Destruction, 25 March 2011, Wollaston College Conference Centre, Mount Claremont* pp. 3-10. Urban Bushland Council, West Perth.

Keighery G (2011) *Common Wildflowers of the Mid-West*. Department of Environment and Conservation, Kensington, WA. 72 p.

Keighery G (2012) A checklist of the naturalized vascular plants of Western Australia. II, changes 1994–2004. *Western Australian Naturalist* **28**, 120-140.

Keighery G (2012) A new species of *Darwinia* (Myrtaceae) from Western Australia. *Western Australian Naturalist* **28**, 116-119.

Keighery G, Keighery B (2012) Vascular flora of Dryandra Woodland (Lol Gray and Montague state forests). *Western Australian Naturalist* **28**, 73-106.

Keighery G, Lyons M, Gibson N, Keighery B (2011) Vascular flora of Leeuwin–Naturaliste National Park. *Conservation Science Western Australia* **8**, 31-60.

Kendrick A, Huisman J, Rule M (2012) Life on the edge: intertidal reefs of the Marmion and Shoalwater Islands marine parks. *Landscope* **27(3)**, 52-58.

Kendrick A, Rule M, Huisman J (2012) Intertidal reef communities of the Marmion & Shoalwater Islands marine parks. Available at: http://www.dec.wa.gov.au/component/option,com_docman/task,doc_download/gid,7006/Itemid,/ Department of Environment and Conservation, Western Australia, Science Division, Information Sheet **44**, DEC, Kensington, WA. 2 p.

Keppel G, van Niel KP, Wardell-Johnson GW, Yates CJ, Byrne M, Mucina L et al. (2012) Refugia: identifying and understanding safe havens for biodiversity under climate change. *Global Ecology and Biogeography* **21**, 393-404.

King R, Burrows N, Dunlop J (2012) The great bilby muster. *Landscope* **27(4)**, 6-8.

Klazenga N, Thiele K (2011) Getting the most out of pathway keys in a web environment (POSTER ABSTRACT). In *IBC2011, XVIII International Botanical Congress: Melbourne, Australia, 23–30 July 2011, Melbourne Congress and Exhibition Centre, Nomenclature Section, 17–22 July, 2011, University of Melbourne: Abstract Book* p. 609.

Klotz A, Macpherson D, Coward D, Gendre B, Boer M, Williams A et al. [Martin R] (2012) GRB 120327A: Zadko optical observations. *GCN Circular* **13164**, p. 1.

Klotz A, Macpherson D, Coward D, Gendre B, Boer M, Williams A et al. [Martin R] (2012) GRB 120422A: Zadko observatory, Gingin optical observations. *GCN Circular* **13250**, p. 1.

Knight K (2012) Water fire suppression system to protect a valuable herbarium collection: is this folly or the future for herbaria? Poster presented at the Fifth Annual Global Plants Initiative Meeting, 9–13 April 2012, Madrid, Spain (POSTER). Department of Environment and Conservation, Kensington, WA. 1 poster.

Koch K, Algar D, Schwenk K (2011) Feral cats: pest in the Indian Ocean (ABSTRACT). In *ICCB 2011: Engaging Society in Conservation: Abstracts: 25th International Congress for Conservation Biology: Auckland, New Zealand, 5–9 December 2011* p. 87. Society for Conservation Biology, Auckland.

Koch K, Penniman J, Algar D, Duvall FP, Schwenk K (2011) Feral cats in Hawai'i: population structure and origin (ABSTRACT). In *Abstracts Book: 19th Annual Hawai'i Conservation Conference: Island Ecosystems, The Year of the Forest: August 2–4, 2011, Hawai'i Convention Center, Honolulu, HI* 40-41. Conference Organising Committee, Honolulu.

Köhler F (2011) Descriptions of new species of the diverse and endemic land snail *Amplirhagada* Iredale, 1933 from rainforest patches across the Kimberley, Western Australia (Pulmonata: Camaenidae). *Records of the Australian Museum* **63**, 167-202.

Langlands PR, Brennan KEC, Ward B (2012) Is the reassembly of an arid spider assemblage following fire deterministic? *Austral Ecology* **37**, 429-439.

Le Roux JJ, Brown GK, Byrne M, Ndlovu J, Richardson DM, Thompson GD et al. (2011) Phylogeographic consequences of different introduction histories of invasive Australian *Acacia* species and *Paraserianthes lophantha* (Fabaceae) in South Africa. *Diversity and Distributions* **17**, 861-871.

Leebens-Mack J, Wickett N, Ayyampalayam S, Barker M, Gonzales MB, Vision TJ et al. [Thiele K] (2011) Phylogenomic analysts of transcriptomes sampled across monocot orders (ABSTRACT). In *IBC2011, XVIII International Botanical Congress: Melbourne, Australia, 23–30 July 2011, Melbourne Congress and Exhibition Centre, Nomenclature Section, 17–22 July, 2011, University of Melbourne: Abstract Book* p. 289.

Limpus C, Whiting S (2011) Sea turtles in the Arafura and Timor seas: management at a regional scale (ABSTRACT). In *Australian Marine Sciences Association, 48th Annual Conference, 3rd–7th July 2011: Book of Abstracts* p. 86. Conference Organising Committee, Fremantle.

Lin SM, Yang SY, Huisman JM (2011) Systematics of *Liagora* with diffuse gonimoblasts based on *rbcL* sequences and carposporophyte development, including the description of the new genera *Neoizziella* and *Macrocarpus* (Liagoraceae, Rhodophyta). *European Journal of Phycology* **46**, 249-262.

Llorens TM, Byrne M, Yates CJ, Nistelberger HM, Coates DJ (2012) Evaluating the influence of different aspects of habitat fragmentation on mating patterns and pollen dispersal in the bird-pollinated *Banksia sphaerocarpa* var. *caesia*. *Molecular Ecology* **21**, 314-328.

Macfarlane TD, Brown AP (2011) Unexpected richness of *Wurmbea* species in the midwest, Murchison and Gascoyne rangelands, Western Australia. *Australasian Plant Conservation* **19(3)**, 25-26.

Macfarlane TD, Hearn RW (2011) An interesting plant community of hypo-saline seasonal lakes in the Muir-Unicup catchment, Western Australia. *Australasian Plant Conservation* **19(3)**, 27-29.

Macpherson D, Coward D, Klotz A, Gendre B, Todd M, Boer M et al. [Williams A, Martin R] (2012) GRB 120320A: Zadko optical observations. *GCN Circular* **13087**, p. 1.

Markey A (2012) A targeted spring flora survey of New Island Bay, Cape Le Grand National Park: a report to Tourism Branch, Department of Environment and Conservation, Kensington. Department of Environment and Conservation, Kensington, WA. 34 p.

Markey AS, Dillon SJ (2011) Flora and vegetation of the banded iron formations of the Yilgarn Craton: northern Yerilgee Hills, Menzies. *Conservation Science Western Australia* **8**, 163-186.

Markey AS, Dillon SJ (2011) Flora and vegetation of the banded iron formations of the Yilgarn Craton: the Johnston Range, Menzies. *Conservation Science Western Australia* **8**, 137-161.

Markey AS, Dillon SJ (2011) Flora and vegetation of the banded iron formations of the Yilgarn Craton: Yalgoo. *Conservation Science Western Australia* **8**, 113-136.

Markey A, Dillon S (2012) Vascular flora of Cane River Conservation Park, Western Australia: a report to the Bush Blitz Program, Australian Biological Resources Study. Department of Environment and Conservation, Kensington, WA. 63 p.

Markey AS, Dillon SJ, Cockerton GTB, Barker RM (2011) *Sida picklesiana* (Malvaceae), a new species from the Murchison–Gascoyne region of Western Australia. *Nuytsia* **21**, 127-137.

Martin R, Monard LAG, Morrell N, Pignata G, Anderson J, Lira P et al. (2011) Supernova 2011ed = Psn J19153440-5437400 and Supernova 2010kx. *Central Bureau for Astronomical Telegrams, Electronic Telegram* **2767**, p. 1.

Maschinski J, Albrecht MA, Monks L, Haskins KE (2012) Appendix 1, Centre for Plant Conservation best reintroduction practice guidelines. In *Plant Reintroduction in a Changing Climate: Promises and Perils* (eds J Maschinski, KE Haskins), pp. 277-306. Island Press, Washington.

Maslin B (2011) *Acacia* and the IBC. *Australian Systematic Botany Society Newsletter* **146**, 2-6.

Maslin BR, Reid JE (2012) *Acacia bartlei* (Leguminosae: Mimosoideae), a new species from near Esperance, Western Australia. *Nuytsia* **22**, 51-56.

Matheny B, Bougher NL, Gates G, Ryberg M (2011) Patterns of diversity in Australian Inocybaceae (Agaricales) (ABSTRACT). In *Fungimap VI: 14–19 July 2011, Denmark, Western Australia* p. 9. Conference Organising Committee, Denmark.

Matheny PB, Bougher NL, Gates GM, Ryberg M (2011) Patterns of diversity in Australian Inocybaceae (Agaricales) (ABSTRACT). *Inoculum* **62(3)**, p. 31.

Matheny PB, Bougher NL, Ryberg M (2011) Key to the genera and major clades of Inocybaceae known from Australia: for the workshop Getting to know the family Inocybaceae: Fungimap VI, Denmark, Western Australia, July 2011. University of Tennessee, Knoxville. 5 p.

McCaw WL (2011) Characteristics of jarrah (*Eucalyptus marginata*) forest at FORESTCHECK monitoring sites in south-west Western Australia: stand structure, litter, woody debris, soil and foliar nutrients. *Australian Forestry* **74**, 254-265.

McCaw L (2011) Quantifying the effectiveness of fuel management in modifying wildfire behaviour: recent examples from Western Australia and Victoria (ABSTRACT). In *Western Australian Bushfire Research Forum 2011, 12 and 13 October 2011: Book of Abstracts* p. 28. Department of Environment and Conservation, Kensington, WA.

McCaw WL, Gould JS, Cheney NP, Ellis PFM, Anderson WR (2012) Changes in behaviour of fire in dry eucalypt forest as fuels increase with age. *Forest Ecology and Management* **271**, 170-181.

McCaw WL, Robinson RM, Williams MR (2011) Integrated biodiversity monitoring for the jarrah (*Eucalyptus marginata*) forest in south-west Western Australia: the FORESTCHECK project. *Australian Forestry* **74**, 240-253.

McClanahan TR, Graham NAJ, MacNeil MA, Muthiga NA, Cinner JE, Bruggemann JH et al. [Wilson SK] (2011) Critical thresholds and tangible targets for ecosystem-based management of coral reef fisheries. *Proceedings of the National Academy of Sciences of the USA* **108**, 17230-17233.

Meissner RA (2011) Biodiversity values of unallocated crown land on Cape Range peninsula, Western Australia. Department of Environment and Conservation, Kensington, WA. 109 p.

Mendham DS, White DA, Battaglia M, McGrath JF, Short TM, Ogden GN et al. [Kinal J] (2011) Soil water depletion and replenishment during first- and early second-rotation *Eucalyptus globulus* plantations with deep soil profiles. *Agricultural and Forest Meteorology* **151**, 1568-1579.

Millar A, Morris K, Asher J (2012) Western Shield: protecting our native fauna. *Landscope* **27(4)**, 9-16.

Millar MA, Byrne M, Barbour E (2012) Characterisation of eleven polymorphic microsatellite DNA markers for Australian sandalwood (*Santalum spicatum*) (R.Br.) A.DC. (Santalaceae). *Conservation Genetics Resources* **4**, 51-53.

Millar MA, Byrne M, Nuberg IK, Sedgley M (2012) High levels of genetic contamination in remnant populations of *Acacia saligna* from a genetically divergent planted stand. *Restoration Ecology* **20**, 260-267.

Millar M, Byrne M, O'Sullivan W (2011) The complex issue of the *Acacia saligna* species complex (POSTER ABSTRACT). In *MEDECOS XII: Linking Science to Resource Management: the International Mediterranean Ecosystems Conference: September 6–9, 2011, Los Angeles, California, United States: Abstracts* p. 204. Conference Organising Committee, Los Angeles.

Millar MA, Coates DJ (2011) Assessment of population genetic variation and structure of *Acacia woodmaniorum*, and its phylogenetic relationship to other *Acacia* species: final report to Karara Mining Ltd by the Department of Environment and Conservation. DEC, Kensington, WA. 39 p.

Millar M, Coates D (2011) Genetic diversity and population persistence in a rare endemic (ABSTRACT). In *MEDECOS XII: Linking Science to Resource Management: the International Mediterranean Ecosystems Conference: September 6–9, 2011, Los Angeles, California, United States: Abstracts* p. 107. Conference Organising Committee, Los Angeles.

Millar M, Coates DJ (2011) Maintaining species connectivity across a historically fragmented niche habitat (ABSTRACT). In *SER2011: World Conference on Ecological Restoration: Re-establishing the Link Between Nature and Culture: Book of Abstracts: 4th World Conference on Ecological Restoration, 20th Annual Meeting of the Society, 2nd Meeting of the Ibero-American and Caribbean Ecological Restoration Network: Merida, Mexico, Sunday August 21–Thursday August 25, 2011* p. 140. Conference Organising Committee, Merida, Mexico.

Millar MA, Byrne M (2012) Assessment of genetic diversity captured in *Acacia saligna* populations from Tigray, Ethiopia: report to World Vision Australia by the Department of Environment and Conservation. DEC, Kensington, WA. 16 p.

Moir ML, Vesk PA, Brennan KEC, Hughes L, Keith DA, McCarthy MA et al. [Coates DJ, Barrett S] (2012) A preliminary assessment of changes in plant-dwelling insects when threatened plants are translocated. *Journal of Insect Conservation* **16**, 367-377.

Moir ML, Vesk PA, Brennan KEC, Poulin R, Hughes L, Keith DA et al [Coates DJ] (2012) Considering extinction of dependent species during translocation, *ex situ* conservation, and assisted migration of threatened hosts. *Conservation Biology* **26**, 199-207.

Monks L, Coates D, Bell T, Bowles M (2012) Determining success criteria for reintroductions of threatened long-lived plants. In *Plant Reintroduction in a Changing Climate: Promises and Perils* (eds J Maschinski, KE Haskins), pp. 189-208. Island Press, Washington.

Monks L, Dillon R, Coates D (2011) The challenges of determining success for reintroductions of threatened long-lived plants (ABSTRACT). In *IBC2011, XVIII International Botanical Congress: Melbourne, Australia, 23–30 July 2011, Melbourne Congress and Exhibition Centre, Nomenclature Section, 17–22 July, 2011, University of Melbourne: Abstract Book* p. 21.

Morris KD (2012) Black rat eradication on Barrow and surrounding islands (ABSTRACT). In *Island Arks Symposium II: 7–9th February 2012, University House, Canberra* p. 37. Conference Organising Committee, Canberra.

Morris KD, Thomas N (2012) A Barrow load of fauna: translocations from an iconic Western Australian island (ABSTRACT). In *Island Arks Symposium II: 7–9th February 2012, University House, Canberra* pp. 60-61. Conference Organising Committee, Canberra.

Muraki Y, Han C, Bennett DP, Suzuki D, Monard LAG, Street R et al. [Martin R, Williams A] (2011) Discovery and mass measurements of a cold, 10 Earth mass

planet and its host star. *Astrophysical Journal* **741**, 1-15.

Nistelberger H, Byrne M, Gibson N (2011) Contrasting evolutionary histories in two phylogeographic lineages of a widespread, woody shrub in Western Australia (ABSTRACT). In *Genetics Society of AustralAsia, Annual Conference 2011: Melbourne, July 10–13th 2011* p. 28. Conference Organising Committee, Melbourne.

O'Donnell AJ, Boer MM, McCaw WL, Grierson PF (2011) Climatic anomalies drive wildfire occurrence and extent in semi-arid shrublands and woodlands of southwest Australia. *Ecosphere* **2**, art127, p. 1-15.

Oliver PM, Doughty P, Palmer R (2012) Hidden biodiversity in rare northern Australian vertebrates: the case of the clawless geckos (Crenadactylus: Diplodactylidae) of the Kimberley. *Wildlife Research* **39**, 429-435.

Pakoa KM, Bertram I, Friedman KJ, Tardy E (2012) Sandfish (*Holothuria scabra*) fisheries in the Pacific region: present status, management overview and outlook for rehabilitation. In *Asia-Pacific Tropical Sea Cucumber Aquaculture: Proceedings of an International Symposium held in Noumea, New Caledonia, 15–17 February 2011* (eds CA Hair, TD Pickering, DJ Mills), ACIAR Proceedings **136**, 168-176. Australian Centre for International Agricultural Research, Canberra.

Palmer R (2012) Diet of the dingo (*Canis lupus dingo*) from the desert uplands of north Queensland. *Queensland Naturalist* **50**, 23-26.

Palmer R, Cramer V, Oliver P (2011) A little gecko tells a big story. *Landscope* **27(1)**, 59-61.

Pearson D (2011) *Snakes of Western Australia*. Department of Environment and Conservation, Kensington, WA. 72 p.

Pennifold M (2012) Aquatic invertebrate communities in Gwambygine Pool following dredging in 2010: report to Wheatbelt Natural Resources Management Inc. Department of Environment and Conservation, Kensington, WA. 18 p.

Pilbeam RA, Howard K, Shearer BL, Hardy GE St J (2011) Phosphite stimulated histological responses of *Eucalyptus marginata* to infection by *Phytophthora cinnamomi*. *Trees: Structure and Function* **25**, 1121-1131.

Pinder A, Cale D, Halse S, Leung A (2012) Waterbird monitoring of the Warden and Gore wetlands in November 2010 and February 2011. Department of Environment and Conservation, Woodvale, WA. 55 p.

Pinder A, Lizamore J (2012) Change in waterbird communities of the Warden wetlands. *WA South Coast Shorebird Network Newsletter* **4**, 2-3.

Pinder A, Quinlan K (2012) Aquatic invertebrate communities of selected springs in the Jurien (Cervantes to Coolimba) region: interim report to Department of Water. Department of Environment and Conservation, Woodvale, WA. 25 p.

Pinder AM, Quinlan K, Cale DJ, Leung AE (2012) Aquatic invertebrates of the Hutt River and Hutt Lagoon catchments, Western Australia. *Journal of the Royal Society of Western Australia* **95**, 29-51.

Plummer JA, Jones CG, Moniodis J, Zulak KG, Barbour EL, Byrne M et al. (2011) Genetic diversity of tropical sandalwood (*Santalum album*) (ABSTRACT). In *Combio2011: Proceedings of the Australian Society for Biochemistry and Molecular Biology, Cairns, Queensland, 25–29 September 2011* p. 86. Conference Organising Committee, Cairns.

Poorter H, Niklas KJ, Reich PB, Oleksyn J, Poot P, Mommer L (2012) Biomass allocation to leaves, stems and roots: meta-analyses of interspecific variation and environmental control. *New Phytologist* **193**, 30-50.

Pratchett MS, Hoey AS, Wilson SK, Messmer V, Graham NAJ (2011) Changes in biodiversity and functioning of reef fish assemblages following coral bleaching and coral loss. *Diversity* **3**, 424-452.

Pratchett MS, Munday PL, Graham NAJ, Kronen M, Pinca S, Friedman K et al. [Wilson SK] (2011) Vulnerability of coastal fisheries in the tropical Pacific to climate change. In *Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate Change* (eds JD Bell, JE Johnson, AJ Hobday), pp. 493-576. Secretariat of the Pacific Community, Noumea.

Prince RIT, Chaloupka M (2012) Estimating demographic parameters for a critically endangered marine species with frequent reproductive omission: hawksbill turtles nesting at Varanus Island, Western Australia. *Marine Biology* **159**, 355-363.

Prior L, McCaw L, Grierson P, Murphy B, Bowman D (2011) Continental contrasts in stand structures of Callitris columellaris (ABSTRACT). *In: Ecological Society of Australia, 2011 Annual Conference: Ecology in Changing Landscapes: Conference Handbook, 21–25 November, 2011, Wrest Point, Hobart, Tasmania* p. 53. Conference Organising Committee, Hobart.

Prober SM, Thiele KR, Rundel PW, Yates CJ, Berry SL, Byrne M et al. [Gosper CR] (2012) Facilitating adaptation of biodiversity to climate change: a conceptual framework applied to the world's largest Mediterranean-climate woodland. *Climatic Change* **110**, 227-248.

Puente-Lelièvre C, Harrington M, Hislop M, Quinn C, Brown E, Crayn, D (2011) Phylogenetic relationships, tempo and patterns of evolution of the Australasian Ericaceae (ABSTRACT). In *IBC2011, XVIII International Botanical Congress: Melbourne, Australia, 23–30 July 2011, Melbourne Congress and Exhibition Centre, Nomenclature Section, 17–22 July, 2011, University of Melbourne: Abstract Book* pp. 282-283.

Radford I, Andersen A (2011) Callitris intratropica as an umbrella for fire-sensitive groups within Australia's tropical savannas (ABSTRACT). *In: Ecological Society of Australia, 2011 Annual Conference: Ecology in Changing Landscapes: Conference Handbook, 21–25 November, 2011, Wrest Point, Hobart, Tasmania* p. 70. Conference Organising Committee, Hobart.

Radford IJ, Fairman R, Cook A (2011) Implications of Kimberley fire ecology research for conservation management (ABSTRACT). In *Western Australian Bushfire Research Forum 2011, 12 and 13 October 2011: Book of Abstracts* p. 21. Department of Environment and Conservation, Kensington, WA.

Rayner K, Chambers B, Johnson B, Morris KD, Mills HR (2012) Spatial and dietary requirements of the chuditch (*Dasyurus geoffroii*) in a semiarid climatic zone. *Australian Mammalogy* **34**, 59-67.

Rea AJ, Burgess TI, Hardy GE St J, Stukely MJC, Jung T (2011) Two novel and potentially endemic species of *Phytophthora* associated with episodic dieback of kwongan vegetation in the south-west of Western Australia. *Plant Pathology* **60**, 1055-1068.

Reisen F, Meyer CP, McCaw L, Powell JC, Tolhurst K, Keywood MD et al. (2011) Impact of smoke from biomass burning on air quality in rural communities in southern Australia. *Atmospheric Environment* **45**, 3944-3953.

Richards JD, Algar D, Hamilton N, Hilmer S, Rolfe J, Onus M, Prince J (2011) Small mammal and reptile

assemblages of the semi-arid woodlands and acacia sandplains in the southern rangelands of Western Australia. *Conservation Science Western Australia* **8**, 1-10.

Richards JD, Hamilton N, Fuller PJ, Algar D, Prince J (2011) Terrestrial bird assemblages of the semi-arid woodlands and acacia sandplains in the southern rangelands of Western Australia. *Conservation Science Western Australia* **8**, 11-21.

Robinson R (2011) Survey techniques for monitoring macrofungi (ABSTRACT). In *Fungimap VI: 14–19 July 2011, Denmark, Western Australia* p. 15. Conference Organising Committee, Denmark.

Robinson R (2011) Surveying and monitoring macrofungi in large-scale land management projects: FORESTCHECK and the Walpole fire mosaic (ABSTRACT). In *Fungimap VI: 14–19 July 2011, Denmark, Western Australia* p. 8. Conference Organising Committee, Denmark.

Robinson R (2012) *Armillaria* root disease in karri regrowth forests. Available at: http://www.dec.wa.gov.au/component/option,com_docman/task,doc_download/gid,7007/Itemid,/ Department of Environment and Conservation, Western Australia, Science Division, Information Sheet **45**, DEC, Kensington, WA. 2 p.

Robinson R (2012) Interactions between fungal communities and fire (ABSTRACT). In *Tasmanian Fungi Festival presents Fungi Conservation and Management Symposium: Thursday 26th and Friday 27th April, 2012, the Old Woolstore Apartment Hotel* p. 9. Symposium Organising Committee, Hobart.

Robinson RM, Williams MR (2011) FORESTCHECK: the response of epigeous macrofungi to silviculture in jarrah (*Eucalyptus marginata*) forest. *Australian Forestry* **74**, 288-302.

Rong J, Bunce M, Wayne A, Pacioni C, Ryan U, Irwin P (2012) A high prevalence of *Theileria penicillata* in woylies (*Bettongia penicillata*). *Experimental Parasitology* **131**, 157-161.

Rule M, Kendrick A, Huisman J (2012) Mangroves of the Shark Bay Marine Park. Available at: http://www.dec.wa.gov.au/component/option,com_docman/task,doc_download/gid,7008/Itemid,/ Department of Environment and Conservation, Western Australia, Science Division, Information Sheet **46**, DEC, Kensington, WA. 2 p.

Rye BL, Hislop M, Shepherd KA, Hollister C (2011) New south-western Australian members of the genus *Petrophile* (Proteaceae: Petrophileae), including a hybrid. *Nuytsia* **21**, 35-67.

Rye B, Trudgen M, Macfarlane T, Lander N (2011) Interactive identification and database for the Myrtaceae tribe Chamelaucieae (ABSTRACT). In *IBC2011, XVIII International Botanical Congress: Melbourne, Australia, 23–30 July 2011, Melbourne Congress and Exhibition Centre, Nomenclature Section, 17–22 July, 2011, University of Melbourne: Abstract Book* p. 675.

Sampey A, Bryce C, Fromont J, Morrison S, Marsh L, Hosie A et al. [Huisman J] (2011) Synthesis of marine species data for the Kimberley region (ABSTRACT). In *Australian Marine Sciences Association, 48th Annual Conference, 3rd–7th July 2011: Book of Abstracts* p. 120. Conference Organising Committee, Fremantle.

Sampson JF, Byrne M (2012) Genetic diversity and multiple origins of polyploid *Atriplex nummularia* Lindl. (Chenopodiaceae). *Biological Journal of the Linnean Society* **105**, 218-230.

Scott P, Barber P, Hardy G, Shearer B (2011) Can a microscopic plant pathogen kill a large tuart tree? Centre of Excellence for Climate Change, Woodland & Forest Health Bulletin **15**, Murdoch University, Murdoch. 2 p.

Shearer BL, Crane CE (2012) Variation within the genus *Lambertia* in efficacy of low-volume aerial phosphite spray for control of *Phytophthora cinnamomi*. *Australasian Plant Pathology* **41**, 47-57.

Shearer BL, Crane CE, Dunne CP (2012) Variation in vegetation cover between shrubland, woodland and forest biomes invaded by *Phytophthora cinnamomi*. *Australasian Plant Pathology* **41**, 413-424.

Shedley E, Coates D, Burrows N (2011) Fire responses of threatened flora in Western Australia. *Australasian Plant Conservation* **19(3)**, 36-37.

Shepherd KA, Moir-Barnetson L, Colmer TD, Veneklaas EJ (2011) Diversity and habitat specialisation among the Australian samphires (subfamily Salicornioideae: Chenopodiaceae) (POSTER ABSTRACT). In *IBC2011, XVIII International Botanical Congress: Melbourne, Australia, 23–30 July 2011, Melbourne Congress and Exhibition Centre, Nomenclature Section, 17–22 July, 2011, University of Melbourne: Abstract Book* p. 640.

Shepherd KA, Sampson J, Thiele K, Byrne M (2011) Taxonomic resolution of *Atriplex* sp. Yeelirrie Station (L.Trotter & A.Douglas LCH 25025) utilising morphological and molecular methods: final report. Department of Environment and Conservation, Kensington, WA. 27 p.

Shepherd KA, Trudgen ME (2011) *Eragrostis surreyana* (Poaceae) an uncommon, habitat restricted new species from the Pilbara bioregion of Western Australia. *Telopea* **13**, 143-148.

Shepherd KA, van Leeuwen SJ (2011) *Tecticornia globulifera* and *T. medusa* (subfamily Salicornioideae: Chenopodiaceae), two new priority samphires from the Fortescue Marsh in the Pilbara region of Western Australia. *Telopea* **13**, 349-358.

Shin I-G, Choi J-Y, Park S-Y, Han C, Gould A, Sumi T et al. [Martin R, Williams A] (2012) Microlensing binaries discovered through high-magnification channel. *Astrophysical Journal* **746**, 1-13.

Shin I-G, Udalski A, Han C, Gould A, Dominik M, Fouqué P et al. [Martin R, Williams A] (2011) OGLE-2005-BLG-018: characterization of full physical and orbital parameters of a gravitational binary lens. *Astrophysical Journal* **735**, 1-8.

Simpson C, Kendrick A (2011) Marine Science Program: summary of activities, outputs and expenditure for 2010/11: report to the Marine Parks and Reserves Authority. Department of Environment and Conservation, Kensington, WA. 83 p.

Sirisena UM, Donnon MJ, Macfarlane TD, Conran JG (2011) Generic relationships within Asparagaceae: Lomandroideae inferred from non-coding chloroplast DNA and morphology (ABSTRACT). In *IBC2011, XVIII International Botanical Congress: Melbourne, Australia, 23–30 July 2011, Melbourne Congress and Exhibition Centre, Nomenclature Section, 17–22 July, 2011, University of Melbourne: Abstract Book* pp. 308-309.

Skowron J, Udalski A, Gould A, Dong S, Monard LAG, Han C et al. [Martin R, Williams A] (2011) Binary microlensing event OGLE-2009-BLG-020 gives verifiable mass, distance, and orbit predictions. *Astrophysical Journal* **738**, 1-21.

Smith H, Pollock K, Waples K, Bradley S, Bejder L (2011) Use of the Robust Design model to estimate abundance and demographic parameters for a coastal bottlenose dolphin (*Tursiops aduncus*) population (ABSTRACT). In *Australian Marine Sciences Association, 48th Annual*

Conference, 3rd–7th July 2011: Book of Abstracts p. 185. Conference Organising Committee, Fremantle.

Sokoloff DD, Remizowa MV, Beer AS, Sadovnikova ES, Yadav SR, Macfarlane TD et al. (2011) Plant architecture and shoot branching patterns in early-divergent aquatic angiosperms, with emphasis on Hydatellaceae (ABSTRACT). In *IBC2011, XVIII International Botanical Congress: Melbourne, Australia, 23–30 July 2011, Melbourne Congress and Exhibition Centre, Nomenclature Section, 17–22 July, 2011, University of Melbourne: Abstract Book* pp. 244-245.

Sokoloff DD, Remizowa MV, Macfarlane TD, Yadav SR, Rudall PJ (2011) Hydatellaceae: a historical review of systematics and ecology. *Rheedea* **21**, 115-138.

Spencer P, Wilson K, Schmitt L, How R, Grimm H, de Tores P (2011) Wildlife carers and translocation programs alter natural genetic patches and have contributed to the recent decline of the western ringtail possum, *Pseudocheirus occidentalis* (ABSTRACT). *Australian Mammal Society Newsletter* **Oct**, 141-142.

Start AN (2011) Fire responses and survival strategies of mistletoes (Loranthaceae) in an arid environment in Western Australia. *Australian Journal of Botany* **59**, 533-542.

Start AN, Burbidge AA, McDowell MC, McKenzie NL (2012) The status of non-volant mammals along a rainfall gradient in the south-west Kimberley, Western Australia. *Australian Mammalogy* **34**, 36-48.

Stukely MJC (2012) New phytophthoras in Western Australia's natural ecosystems. *Microbiology Australia* **33**, 31-33.

Stukely M, Webster J, Ciampini J (2011) Vegetation Health Service: annual report, 2010–2011, Phytophthora detection. Department of Environment and Conservation, Kensington, WA. 17 p.

Stylianou V, Stock W, Prober S, Byrne M, Froend R (2011) Trait plasticity of a widespread eucalypt along a climate gradient in south-west Australia (POSTER ABSTRACT). *In: Ecological Society of Australia, 2011 Annual Conference: Ecology in Changing Landscapes: Conference Handbook, 21–25 November, 2011, Wrest Point, Hobart, Tasmania* p. 235. Conference Organising Committee, Hobart.

Sullivan AL, McCaw WL, Cruz MG, Matthew S, Ellis PF (2012) Fuel, fire weather and fire behaviour in Australian ecosystems. In *Flammable Australia: Fire Regimes, Biodiversity and Ecosystems in a Changing World* (eds RA Bradstock, AM Gill, RJ Williams), pp. 51-77. CSIRO Publishing, Collingwood.

Thiele K (2011) The eflora of anywhere and the eflora of everywhere: floras in a highly connected world (ABSTRACT). In *IBC2011, XVIII International Botanical Congress: Melbourne, Australia, 23–30 July 2011, Melbourne Congress and Exhibition Centre, Nomenclature Section, 17–22 July, 2011, University of Melbourne: Abstract Book* p. 336.

Thiele K (2011) Making biodiversity information available to the public (ABSTRACT). In *Fungimap VI: 14–19 July 2011, Denmark, Western Australia* p. 6. Conference Organising Committee, Denmark.

Thiele K (2011) WA Herbarium: turns over a new leaf. *Landscope* **27(1)**, 10-17.

Thiele KR, Funk VA, Iwatsuki K, Morat P, Peng C-I, Raven PH et al. (2011) The controversy over the retypification of *Acacia* Mill. with an Australian type: a pragmatic view. *Taxon* **60**, 194-198.

Thompson GD, Bellstedt DU, Byrne M, Millar MA, Richardson DM, Wilson JRU et al. (2012) Cultivation shapes genetic novelty in a globally important invader. *Molecular Ecology* **21**, 3187-3199.

Thompson WA, Sheehy N (2011) Flora and vegetation of banded iron formations of the Yilgarn Craton: the Lake Mason zone of the Gum Creek greenstone belt. *Conservation Science Western Australia* **8**, 77-94.

Thompson WA, Sheehy NB (2011) Flora and vegetation of banded iron formations of the Yilgarn Craton: the Lee Steere Range. *Conservation Science Western Australia* **8**, 61-76.

Thompson WA, Sheehy NB (2011) Flora and vegetation of banded iron formations of the Yilgarn Craton: the Montague Range zone of the Gum Creek greenstone belt. *Conservation Science Western Australia* **8**, 95-111.

Thums M, Meekan M, Whiting S, Reisser J, Pendoley K, Harcourt R et al. (2012) Final report April 2012: understanding the early offshore migration patterns of turtle hatchlings and the effects of anthropogenic light: a pilot study. University of Western Australia, Crawley. 15 p.

Tiller C, Comer S, Burbidge A (2011) Translocations of the endangered noisy scrub-bird as a mechanism for increasing resilience in changing climates (ABSTRACT). *In: Ecological Society of Australia, 2011 Annual Conference: Ecology in Changing Landscapes: Conference Handbook, 21–25 November, 2011, Wrest Point, Hobart, Tasmania* p. 268. Conference Organising Committee, Hobart.

Tolfree S, Wayne A (2012) Help save woylies. Available at: http://www.youtube.com/watch?v=wRgsfseHrAA (VIDEO). Department of Environment and Conservation, Manjimup. 1 video.

Underwood R (2011) *A Botanical Journey: the Story of the Western Australian Herbarium*. Department of Environment and Conservation, Perth. 275 p.

Van Heurck P (2011) Mosaic fires not wildfires? Logistic lessons from beetles in south-west Australia (ABSTRACT). In *Western Australian Bushfire Research Forum 2011, 12 and 13 October 2011: Book of Abstracts* p. 17. Department of Environment and Conservation, Kensington, WA.

Ward B, Robinson RM, Cranfield RJ, Williams MR (2011) FORESTCHECK: the response of vascular flora to silviculture in jarrah (*Eucalyptus marginata*) forest. *Australian Forestry* **74**, 276-287.

Wardell-Johnson G, Burrows N (2011) Genetic diversity and population persistence in a rare endemic (ABSTRACT). In *MEDECOS XII: Linking Science to Resource Management: the International Mediterranean Ecosystems Conference: September 6–9, 2011, Los Angeles, California, United States: Abstracts* p. 176. Conference Organising Committee, Los Angeles.

Wayne AF, Liddelow GL, Williams MR (2011) FORESTCHECK: terrestrial vertebrate associations with fox control and silviculture in jarrah (*Eucalyptus marginata*) forest. *Australian Forestry* **74**, 336-349.

Wayne A, Maxwell M, Nicholls P, Pacioni C, Reiss A, Smith A et al. [Vellios C, Ward C, Wayne J, Wilson I, Williams M] (2011) The Woylie Conservation Research Project: investigating the cause(s) of woylie declines in the Upper Warren region: progress report, December 2011. Department of Environment and Conservation, Manjimup. 73 p.

Webber BL, Yates CJ, Le Maitre DC, Scott JK, Kriticos DJ, Ota N et al. [McNeill A] (2011) Modelling horses for novel climate courses: insights from projecting potential distributions of native and alien Australian acacias with correlative and mechanistic models. *Diversity and Distributions* **17**, 978-1000.

Weeks AR, Sgro CM, Young AG, Frankham R, Mitchell NJ, Miller KA et al. [Byrne M, Coates DJ] (2011) Assessing the benefits and risks of translocations in changing environments: a genetic perspective. *Evolutionary Applications* **4**, 709-725.

Wege JA (2011) A taxonomic revision of the *Stylidium despectum* group (Stylidiaceae) from southern Australia. *Australian Systematic Botany* **24**, 375-404.

Wege JA (2012) Navigating the floral Milky Way: the taxonomy of the microgeophytic triggerplants (*Stylidium petiolare* and allies: Stylidiaceae). *Australian Systematic Botany* **25**, 138-169.

Wege JA, Shepherd KA, Butcher R, Thiele KR (2011) Targeted taxonomy in Western Australia: positives and pitfalls (ABSTRACT). In *IBC2011, XVIII International Botanical Congress: Melbourne, Australia, 23–30 July 2011, Melbourne Congress and Exhibition Centre, Nomenclature Section, 17–22 July, 2011, University of Melbourne: Abstract Book* pp. 425-426.

Wheeler J (2011) *Common Trees of the South-West Forests*. Department of Environment and Conservation, Kensington, WA. 72 p.

Whitford K (2011) Cording to reduce soil disturbance during timber harvesting. Available at: http://www.dec.wa.gov.au/component/option,com_docman/task,doc_download/gid,5919/Itemid,/ Department of Environment and Conservation, Western Australia, Science Division, Information Sheet **43**, DEC, Kensington, WA. 2 p.

Whitford KR, Mellican AE (2011) Intensity, extent and persistence of soil disturbance caused by timber harvesting in jarrah (*Eucalyptus marginata*) forest on FORESTCHECK monitoring sites. *Australian Forestry* **74**, 266-275.

Whiting SD (2011) Shallow water foraging using a shoreline boundary by the Indo-Pacific humpback dolphin *Sousa chinensis* in northern Australia. *Northern Territory Naturalist* **23**, 39-44.

Whiting SD, Whiting AU (2011) Predation by the saltwater crocodile (*Crocodylus porosus*) on sea turtle adults, eggs and hatchlings. *Chelonian Conservation and Biology* **10**, 198-205.

Whitlock BA, Hale AM, Indorf JL, Wilkins CF (2011) Polyphyly of *Rulingia* and *Commersonia* (Lasiopetaleae, Malvaceae s.l.). *Australian Systematic Botany* **24**, 215-225.

Wilkins C, Kern S, Rathbone D, Markey A (2011) *Rare and Poorly Known Flora of the Ravensthorpe Range and Bandalup Hill*. Department of Environment and Conservation, Perth. 170 p.

Wilkins CF, Trudgen ME (2012) A new species of *Gompholobium* (Fabaceae: Mirbelieae) from the Pilbara bioregion of Western Australia. *Nuytsia* **22**, 31-40.

Wilkins CF, Whitlock BA (2011) A new Australian genus *Androcalva* separated from *Commersonia* (Malvaceae s.l. or Byttneriaceae). *Australian Systematic Botany* **24**, 284-349.

Wilkins CF, Whitlock BA (2011) Revision of *Commersonia* including *Rulingia* (Malvaceae s.l. or Byttneriaceae). *Australian Systematic Botany* **24**, 226-238.

Willers N, Mawson P, Morris K, Bencini R (2011) Biology and population dynamics of the black-flanked rock-wallaby (*Petrogale lateralis lateralis*) in the central wheatbelt of Western Australia. *Australian Mammalogy* **33**, 117-127.

Williams AAE (2011) Report on Pilbara rare sun-moth survey, September 2011. Department of Environment and Conservation, Woodvale, WA. 5 p.

Williams M (2011) Graceful sun-moth results 2011. *Bushland News* **80**, p. 5.

Wills A (2011) Preliminary observations of bulls-eye borer (*Phoracantha acanthocera*) on marri (*Corymbia calophylla*): a bellwether for effects of climate trends on ecosystem quality in forest of south-west Western Australia? Department of Environment and Conservation, Kensington, WA. 19 p.

Wills A (2012) Notes on terrestrial Oligochaeta (earthworms) collected c. 2 km SSE of Preston Beach town, Western Australia, December 2011. Department of Environment and Conservation, Kensington, WA. 5 p.

Wills AJ (2012) Report on terrestrial Oligochaeta (earthworms) collected from the Newmont Asia Pacific Boddington gold mine residue disposal area and waste rock dump expansion, c. 15 km northwest of Boddington, Western Australia, 16 August–30 September 2011. Draft. Department of Environment and Conservation, Kensington, WA. 22 p.

Wilson S, Holmes T, Depczynski M (2012) Habitat associations of juvenile coral reef fish. Available at: http://www.dec.wa.gov.au/component/option,com_docman/task,doc_download/gid,7139/Itemid,/. Department of Environment and Conservation, Western Australia, Science Division, Information Sheet **47**, DEC, Kensington, WA. 2 p.

Wittkuhn RS, McCaw L, Wills AJ, Robinson R, Andersen AN, van Heurck P et al. [Farr J, Liddelow G, Cranfield R] (2011) Impacts of variation in fire interval sequences on species richness and composition (ABSTRACT). In *Western Australian Bushfire Research Forum 2011, 12 and 13 October 2011: Book of Abstracts* p. 16. Department of Environment and Conservation, Kensington, WA.

Wotton BM, Gould JS, McCaw WL, Cheney NP, Taylor SW (2012) Flame temperature and residence time of fires in dry eucalypt forest. *International Journal of Wildland Fire* **21**, 270-281.

Yates CJ, Gibson N, Pettit NE, Dillon R, Palmer R (2011) The ecological relationships and demography of restricted ironstone endemic plant species: implications for conservation. *Australian Journal of Botany* **59**, 692-700.

Yates CJ, Gosper CR, Prober SM (2011) Fire, fragmentation, weeds and conservation of plant diversity in wheatbelt nature reserves (ABSTRACT). In *Western Australian Bushfire Research Forum 2011, 12 and 13 October 2011: Book of Abstracts* p. 23. Department of Environment and Conservation, Kensington, WA.

CURRENT COLLABORATION WITH ACADEMIA (STUDENT PROJECTS)

DEC Officer	Student	Project Title	Degree / level	Duration	University Academic	University
Abbott, Ian	P van Heurck	The compositional, structural, and functional succession of beetle communities in habitat mosaics created by three different fire regimes in the southern forests of Western Australia	PhD	2005–2012	Prof J Majer	Curtin University
Algar, David	A Coddou	Baiting effectiveness for introduced rats (*Rattus* sp.) on Christmas Island	Hons	2012	Dr H Mills	The University of Western Australia
Algar, David	N Dybing	Disease potential of feral cats (*Felis catus*) and rodents on island and mainland Western Australia	PhD	2011–2013	Dr P Adams	Murdoch University
Algar, David	G Hayes	Dietary study of feral cats (*Felis catus*) and black rats (*Rattus rattus*) to determine predatory impact and identify bait preference for use in a rat eradication program	Hons	2012	Dr H Mills	The University of Western Australia
Algar, David	M Johnston	Development of Curiosity feral cat bait	PhD	2012–2014	Dr D Whisson	Deakin University
Algar, David	K Koch	Genetic diversity and phylogeography of Australian cats	PhD	2009–2012	Dr K Schwenk	Johan Wolfgang Gothe University
Algar, David	Low Bing Wen	Black rats in paradise—abundance and home range size on Christmas Island	Hons	2012	Dr H Mills	The University of Western Australia
Burbidge, Allan	C Polson-Brown	Use by birds of revegetated remnants on Rottnest Island	Hons	2012	Dr R Davis	Edith Cowan University
Byrne, Margaret	E Dalmaris	Physiology of Wandoo decline	PhD	2003–2011	Dr E Veneklauss, Dr P Poot	The University of Western Australia
Byrne, Margaret	J Moniodis	The genetics, essential oil composition and factors controlling the biosynthesis of sesquiterpenes in Western Australia sandalwood	PhD	2010–2012	Dr J Plummer, Dr L Barbour	The University of Western Australia
Byrne, Margaret; Coates,	H Nistelberger	Ancient, terrestrial islands in a semi-arid landscape: Patterns of genetic diversity	PhD	2010–2013	Dr D Roberts	The University of Western Australia

DEC Officer	Student	Project Title	Degree / level	Duration	University Academic	University
David		in regional endemics of the Yilgarn Banded Iron Formations				
Byrne, Margaret	V Stylianou	Morphological and physiological traits of a widespread and restricted eucalypt species along a rainfall gradient in south-west Australia	Hons	2011	Dr W Stock, Dr S Prober (CSIRO)	Edith Cowan University
de Tores, Paul	H Grimm	Possum ecology and health on the Geographe Coastal Plain	PhD	2006–2012	Dr K Warren, Prof I Robertson, Assoc Prof M Calver	Murdoch University
de Tores, Paul	C Love	The fate of western ringtail possums left *in situ* during habitat clearing	Hons	2011	Assoc Prof R Bencini, Dr B Chambers	The University of Western Australia
de Tores, Paul	E McKeown	Identification of the attributes of remnant habitat patches known to support extant populations of the western ringtail possum	PhD	2011–2014	Assoc Prof R Bencini	The University of Western Australia
de Tores, Paul	M Rowland	Western ringtail possum survivorship and use of retained habitat patches at Dalyellup	Hons	2011	Assoc Prof R Bencini	The University of Western Australia
de Tores, Paul	K Yokochi	The efficacy of rope bridges in mitigating negative effects of roads on populations of possums in south-west Western Australia	PhD	2009–2012	Assoc Prof R Bencini, J Kennington	The University of Western Australia
Farr, Janet	K Ironside	Trophic dynamics of predatory invertebrates in jarrah forests of differing fire history	MSc	2006–2013	Dr J Prince, Dr P Grierson	The University of Western Australia
Field, Stuart	J Turner	Monitoring coral size-frequency distribution, an investigation into digital methods	MSc	2012	Prof N Polunin	University of Newcastle
Friedman, Kim; Bancroft, Kevin	E Do Khac	Asset management study on the status of coastal biological communities of Ningaloo Marine Park.	Yr 4 intern	2011–2012	Ms M Issartel	Paris Institute of Technology
Friedman, Kim	A Swarts	How best can managers measure on-going change in coral condition and related pressure metrics at sites where there is high levels of human use?	Hons	2012–2013	Dr M O'Leary	Curtin University of Technology
Friend, Tony	J Austen	Trypanosomes of some Western Australian mammals: phylogenetics	PhD	2006–2012	Dr U Ryan	Murdoch University

DEC Officer	Student	Project Title	Degree / level	Duration	University Academic	University
		and ecology				
Friend, Tony	J Pridham	Finding a dietary surrogate for Gilbert's potoroo (*Potorous gilbertii*)	Hons	2012	Dr P Speldewinde	The University of Western Australia
Huisman, John	R Dixon	Systematics of *Sargassum* (Phaeophyceae) in Australia	PhD	2008–2012	Dr J Huisman	Murdoch University
Keighery, Greg	T Hevroy	Molecular taxonomy, phylogeography and population genetics of the *Grevillea thelemanniana* complex	PhD	2010–2012	Asst Prof M Moody (Texas), S Krauss (BGPA)	The University of Western Australia
Kendrick, Alan; Wilson Shaun	A Turco	The role of *Kyphosus* spp. in reef ecosystems	PhD	2012–2015	Assoc Prof G Hyndes	Edith Cowan University
Kendrick, Alan	F Vitelli	Feeding ecology of *Pomacentridae* and its ecological role in fish herbivory in temperate algal-dominated reefs	MSc	2012–2013	Assoc Prof G Hyndes	Edith Cowan University
Kendrick, Alan; Rule, Mike	Various	Marine and Coastal Management Course	3rd Year	2011	Assoc Prof G Hyndes, Prof P Lavery	Edith Cowan University
Macfarlane, Terry	IA Raheem	Systematic and evolutionary studies of the eastern and southern Australian clade of the genus *Hibbertia Andrews* subgenus *Hemistema* (Thouars) JW Horn	PhD	2009–2012	Dr JG Conran	University of Adelaide
Marlow, Nicky	J Cruz	Ecology of the common brushtail possum in the northern jarrah forest in relation to predation and resource availability	PhD	2007–2012	Dr L Leung	University of Queensland
McCaw, Lachie	M Peace	Fire weather	MSc	2010–2012	Dr T Mattner, Dr G Mills, Dr J Keppert	Adelaide University, Centre for Australian Weather and Climate Research
Morris, Keith	K Bettink	Ecology and taxonomic differentiation in the Australian water rat and implications for its conservation status in Western Australia	MSc	2010–2014	Dr H Mills	The University of Western Australia
Morris, Keith	J Dunlop	Factors affecting fauna translocation success	PhD	2010–2012	Prof A Thompson	Murdoch University
Morris, Keith	R Thavomkanlapacai	Genetic consequences of mammal translocations in	PhD	2011–2014	Dr H Mills	The University of Western

DEC Officer	Student	Project Title	Degree / level	Duration	University Academic	University
		Western Australia				Australia
Pinder, Adrian	J Lizamore	Nutrient movement and its impact on aquatic invertebrate as food source of waterbirds between different wetland suites within the Lake Warden Wetland System	PhD	2011–2015	Dr R Vogwill	The University of Western Australia
Poot, Pieter; Moody, Michael; Coates, David	C Allen	Factors that affect seedling establishment and the implications for the translocation of species at risk of extinction	PhD	2010–2013	Asst Prof P Poot, Asst Prof M Moody	The University of Western Australia
Poot, Pieter; Moody, Michael	M Hocking	Habitat characteristics that affect survival and growth of two translocated threatened flora species, *Acacia awestoniana* and *Banksia ionthocarpa* ssp. *ionthocarpa* in south-western Australia	Hons	2011	Asst Prof P Poot, Asst Prof M Moody	The University of Western Australia
Radford, Ian	G Daniel	Kimberley remote sensing vegetation structure	MSc	2011	Prof L Mucina	Curtin University
Radford, Ian	H McGregor	Mammal declines in northern Australia: Science for conservation and recovery	PhD	2010–2014	Prof C Johnson	University of Tasmania
Robinson, Richard	F Tovar	Fungi causing decay in coppiced bluegum stumps	PhD	2006–2012	Dr T Burgess, Dr G St J Hardy	Murdoch University
Shearer, Bryan	P Staskowski	Mechanisms of phosphite action	PhD	2006–2011	Dr G Hardy	Murdoch University
Simpson, Chris	A Hill	Factors influencing the establishment of marine protected areas in Western Australia	PhD	2008–2011	Dr S Shea	Notre Dame University
Stukely, Mike	A Rea	Classical and molecular taxonomy and pathogenicity testing of *Phytophthora* species	PhD	2007–2012	Dr G Hardy	Murdoch University
Stukely, Mike	A Simamora	Multiple new *Phytophthora* species from Western Australia: taxonomy, pathogenicity, and disease control	PhD	2011–2014	Prof G Hardy, Dr T Burgess	Murdoch University
van Leeuwen, Stephen	J Harvey	Regional variability in salmon gum communities in the Great Western Woodlands	MSc	2011-2013	Prof L Mucina, Dr S Prober (CSIRO)	Curtin University
Wayne, Adrian	Y Abdad	Rickettsial infections in wildlife and humans in Western Australia	PhD	2006–2012	Dr S Fenwick	Murdoch University

DEC Officer	Student	Project Title	Degree / level	Duration	University Academic	University
Wayne, Adrian	K Bain	Ecological study of the quokka (*Setonix brachyurus*) in the southern forests of south-west Western Australia	PhD	2006–2013	Assoc Prof R Bencini	The University of Western Australia
Wayne, Adrian; Morris, Keith	H Burmej	Ectoparasites of threatened mammals in Western Australia: biodiversity and impact	PhD	2007–2012	Prof A Thompson, Dr A Smith	Murdoch University
Wayne, Adrian	G Kaewmongkol	*Bartonella* infections in wildlife and domestic animals in Western Australia	PhD	2010–1212	Dr S Fenwick	Murdoch University
Wayne, Adrian; Morris, Keith	S Pan	*Toxoplasma gondii* infection and atypical genotypes in Western Australian wildlife species	PhD	2008–2012	Prof A Thompson	Murdoch University
Wayne, Adrian	K Skogvold	A comparative health and disease investigation in the woylie—captive vs free-range enclosure vs wild	MSc	2011–2013	Dr K Warren, Dr S Vitali, Dr C Holyoak, Dr C Monaghan	Murdoch University
Wayne, Adrian	C Thompson	Transmission dynamics of trypanosomes in declining, stable and enclosed populations of brush-tailed bettongs	PhD	2010–2013	Prof A Thompson	Murdoch University
Wayne, Adrian	A Worth	The role of *Toxoplasma gondii* in declining populations of the woylie (*Bettongia pencillata obibyi*)	PhD	2011–2013	Prof A Thompson	Murdoch University
Wayne, Adrian	G Yeatman	Wildlife ecology in the Perup Sanctuary	PhD	2011–2013	Dr H Mills	The University of Western Australia
Wayne, Adrian	K Zosky	Food resources and woylie declines in south-west Western Australia	PhD	2007–2012	Dr K Bryant, Dr M Calver	Murdoch University
Whitford, Kim	E W Smithers	Ecosystem carbon dynamics in bauxite mining in jarrah (*Eucalyptus marginata*) forests in south-western Australia	MSc	2011–2012	Prof R Harper	Murdoch University
Whiting, Scott	X Hoenner	The nesting and post-nesting ecology of hawksbill turtles in northern Australia	PhD	2009–2012	Dr C McMahon	Charles Darwin University
Whiting, Scott	J Tedeschi	Assessing the resilience of marine turtle embryos to extreme temperatures	PhD	2011	Dr N Mitchell	The University of Western Australia
Wilson, Shaun	E Ashworth	Quantitative diet analysis of four mesopredators from Ningaloo Reef, Western Australia	MSc	2012	Dr D Banaru	Aix-Marseille Université, France

DEC Officer	Student	Project Title	Degree / level	Duration	University Academic	University
Wilson, Shaun	J Goetze	Variation in the intensity of periodic harvests in Fijian tabu areas and the effect on reef fish assemblages	PhD	2012–2015	E Harvey	The University of Western Australia
Wilson, Shaun, James Moore	E Josephitis	Comparison of three photographic techniques for analysis of coral reef bleaching	3rd year	2011	T Cummings	Rollins College
Yates, Colin	A Cochrane	Population variation in seed and seedling traits along a climate gradient: plant population persistence in south-west- Western australia under a changing climate	PhD	2010–2013	Dr A Nicotre, Dr G Hoyle	Australian National University
Yates, Colin	A Williams	Climate change impacts on the northern sandplain kwongan vegetation of south-western Australia	PhD	2010–2013	Dr N Enright	Murdoch University

EXTERNAL PARTNERSHIPS

Partnership Name i.e. CRC, Govt Dept, University, Industry, Other (sponsorships etc.)	Project	External funding and source	DEC Involvement
ARC Linkage, Curtin University, The University of Western Australia, Saskatchewan University, Royal Botanic Gardens Kew, AAMHatch	Protecting the safe havens: will granite outcrop environments serve as refuges for flora threatened by anthropogenic climate change?	$330K 2009–2012	C Yates (0.2), M Byrne (0.1)
ARC Linkage, University of Sydney, Department of Society, Environment Water Population and Communities, Australian Reptile Park	Predicting the ecological impact of cane toads on native fauna of north western Australia	$503K for three years	D Pearson (0.5) $20K cash for three years; $112K in kind
ARC Linkage, Karara Mining Ltd and the University of Western Australia	Managing genetic diversity and evolutionary processes in foundation species for landscape restoration in the midwest of Western Australia	$527K for three years	D Coates (0.2), M Byrne (0.2), M Millar (0.9)
ARC Linkage, The University of Western Australia, Chevron, Rio Tinto Iron Ore, Botanic Parks and Gardens Authority	Defining biologically significant units in spinifex (*Triodia* spp.) for improved ecological restoration in arid Australia	$549K over four years	K Thiele (0.05)
Atlas of Living Australia	IdentifyLife, a new platform for collaborarative development of identification tools	$57K p.a. for four years	K Thiele (0.5)
ARC Linkage, The University of Western Australia	Automation of species recognition and size measurement of fish from underwater stereo-video imagery	$436K over three years	S Wilson (0.01); 5K cash and 5K in kind
Australian Biological Resources Study	Bush Blitz: reserve surveys and tactical taxonomy	$8K for 2009–2010; $5K for 2010–2011	T Macfarlane (0.1)
Australian Biological Resources Study	Bush Blitz: Cane River Conservation Park survey	$4K	M Cowan, (0.1), A Markey (0.1), S Dillon (0.05)
Australian Biological Resources Study	Bush Blitz: ex-Credo Station survey	$8K	M Cowan, (0.1), N Gibson (0.1), M Langley (0.1), N Guthrie (0.1)
Australian Biological Resources Study via Adelaide and Murdoch Universities	Marine Benthic Algae of the Great Barrier Reef	ABRS (to Murdoch) $14K p.a. 2009–2011	J Huisman (0.25)
Australian Institute of Marine Science	Coral reef fish recruitment study	AIMS funded field trip	S Wilson (0.1), T Holmes (0.1)
Australian Institute of Marine Science, Australian National University, The University of Western Australia	Ningaloo Seasonal Seaweeds	$30K	S Wilson (0.05), K Murray (0.15), T Holmes (0.05)
Australian Institute of Marine Science, CSIRO Marine and	2010–2011 Western Australian regional-scale coral	Nil	J Moore (0.3), S Wilson (0.01)

Partnership Name i.e. CRC, Govt Dept, University, Industry, Other (sponsorships etc.)	Project	External funding and source	DEC Involvement
Atmospheric Research, Department of Fisheries	bleaching study		
Australian Institute of Marine Science, CSIRO Marine and Atmospheric Research, Department of Fisheries	Temporal and spatial variation in coral cover on Western Australian reefs	Nil	C Speed (0.5), S Wilson (0.1)
Australian Marine Science Association (WA)	Rottnest Young Scientist Workshop	Nil	J Moore (0.01)
Australian Museum	Kimberley islands biodiversity asset identification	$5K in kind	L Gibson (0.7), F Koehler (1.0), V Kessner (0.75)
Australian Wildlife Conservancy	Establishment of translocated populations of critically endangered *Acacia imitans* and *A. unguicula*	AWC provides ongoing care and maintenance	R Dillon (0.08) $15K in kind for translocation establishment (incl. fencing)
BHP Billiton Iron Ore and other Pilbara Mining Companies	Ecology and management of northern quoll in the Pilbara	$350K p.a. for 10 years (2010–2019)	K Morris (0.01), A Cook (1.0)
BHP Billiton Iron Ore	Identification Botanist position at the Western Australian Herbarium	$105K	S Dillon (1.0)
BHP Billiton Uranium	Taxonomic resolution of *Atriplex* sp. Yeelirrie utilising morphological and molecular methods	$179K	K Shepherd (0.5), M Byrne (0.1)
Birds Australia	Shark Bay shorebird survey	$2K (2010)	K Onton (0.03) $6,500 in kind, DEC Shark Bay
Botanic Gardens and Parks Authority	Fungi surveys of Bold Park and Kings Park	$26K	N Bougher (0.1)
Bushfire CRC	Bushfire occurrence and fire growth modelling	Nil	L McCaw (0.1)
Caring for our Country	Eradication of exotic rodents from six islands of high conservation value	$890K 2010–2014	K Morris (0.3), B Muir (0.3), R Palmer (1.0)
Caring for our Country	Western desert fire project	$317K over two years	N Burrows (0.1), G Behn (0.1), C Rummery (0.1)
Cazaly Iron Ore Pty Ltd, Botanica Consulting	Assessment of genetic processes in *Lepidosperma* sp. Parker Range and *Lepidosperma* sp. Mt Caudan	$298K 2012–2013	M Byrne (0.05)
Charles Darwin University	Assessing spatial and demographic structure of anthropogenic mortality on Australasian marine turtles	$300K 2012–2014 North Australian Marine Research Alliance	S Whiting (0.05)
Chevron Australia	Translocations of mammals from Barrow Island—offset program	ca. $1.4M p.a. 2009–2014, $500K p.a. 2015–2019	K Morris (0.10), N Thomas (0.8), K Rayner (1.0), J Angus (0.5), J Dunlop (1.0), B Johnson 0.3), B Muir

Partnership Name i.e. CRC, Govt Dept, University, Industry, Other (sponsorships etc.)	Project	External funding and source	DEC Involvement
			(0.3), S Garretson (1.0)
Clarion U and Oil Region Astronomical Society	Internet telescope	$1K	R Martin (0.02), A Verveer (0.1)
CSIRO Ecosystem Sciences	Pilbara Biological Survey biodiversity GDM modelling/gap analysis: terrestrial fauna and wetland flora and fauna	Nil	A Pinder (0.2), L Gibson (0.2), M Lyons (0.2), A Burbidge (0.2), N McKenzie (0.2)
CSIRO, Edith Cowan University, University of Tasmania	Climate-resilient vegetation of multi-use landscapes: exploiting genetic variability in widespread species	NCCARF $298K 2011–2013	M Byrne (0.1)
CSIRO Marine and Atmospheric Research	What is the role of predators at Ningaloo and how are they impacted by human use?	$55K in kind (2009–2012)	S Wilson (0.1), T Holmes (0.1) DEC contribution $10K
CSIRO, Australian Wildlife Conservancy	Explaining and predicting the occurrence of Night Parrots (*Pezoporus occidentalis*) using GIS and ecological modelling	$38K	A Burbidge (0.05)
Curtin University, Department Agriculture and Food	Pilbara Biological Survey: ant identifications	Nil	N Guthrie (0.1)
Department of Regional Australia, Regional Development and Local Government	Christmas Island cat and rat management plan (stage 2B)	$450K	D Algar (0.3), N Hamilton (0.5)
DSE (Victoria) and Department of Society, Environment Water Population and Communities (DSEWPaC)	PAPP toxicosis and cat bait pellet development	$250K DSEWPaC to DSE	D Algar (0.1)
Edith Cowan University	Monitoring movement patterns of marine fauna using Vemco VRAP Acoustic tracking system	Nil	A Kendrick (0.01), S Wilson (0.01)
Edith Cowan University	Spatial and temporal patterns in benthic invertebrate communities of the Walpole and Nornalup Inlets Marine Park	Nil	A Kendrick (0.05), M Rule (0.05)
Fortescue Metals Group Ltd	Baiting feral cats on the Fortescue Marsh	$600K	D Algar (0.1)
Future Farm Industries CRC	Management of weed and genetic risk in perennial landuse systems	$257K for 2011–20114	M Byrne (0.2), B Macdonald (0.2)
Gorgon Net Conservation Benefits	Cat eradication on Dirk Hartog Island	$200K	D Algar (0.5), M Onus (1.0), J Rolfe (1.0)
International Centre for Radio Astronomy Research, The University of Western Australia,	Imaging and CCD Photometry of Transient Objects	Nil	A Williams (0.2)

Partnership Name i.e. CRC, Govt Dept, University, Industry, Other (sponsorships etc.)	Project	External funding and source	DEC Involvement
Curtin University			
International Science Linkages	Resolving determinants of plant diversity and vegetation structure at different spatial scales for the conservation of high rainfall mediterranean-climate ecosystems	$5K one off	Access to databases
James Cook University	Investigations into the distribution of coral disease at the Montebello Barrow Island MPAs	Nil	S Field (0.02)
Kimberley Land Council	Kimberley islands biological survey—indigenous liaison and participation	Nil	L Gibson (0.7), N McKenzie (0.3)
Lotteries West	Insect databasing—DEC's insect collection	$7.4K final funding	One database person (0.05)
Lowell Observatory, USA University of Maryland, USA	Imaging and spectrophotometry of comets	Nil	A Williams (0.01), A Verveer (0.05)
Millennium Seedbank Project	Seed collection, storage and biology	$128K p.a. to 2011	A Cochrane (0.8), D Coates (0.1)
Microlensing Network for the Detection of Small Terrestrial EcoPlanets	Monitoring gravitational microlenses	Nil	R Martin (0.2), A Williams (0.25)
Murdoch University (Aquatic Ecosystems Research Group)	Macrophytes, macroalgae, phytoplankton and macroinvertebrates of Vasse–Wonnerup	$22K in 2010–2011	J Lane (0.01), A Clarke (0.03)
Murdoch University (Centre for Fish, Fisheries & Aquatic Ecosystems Research)	Fish populations and invasive species of Vasse–Wonnerup Ramsar Site	$79K in 2011–2012 Caring for our Country	J Lane (0.01), A Clarke (0.04)
Murdoch University (Centre for Fish, Fisheries & Aquatic Ecosystems Research)	Fishes and invertebrates of the Vasse–Wonnerup Ramsar Site	$14K in 2011–2012 (South West Catchments Council)	J Lane (0.01), A Clarke (0.02)
Murdoch University	Epidemiology of marri canker	Nil	B Shearer (0.4)
Murdoch University	Taxonomic studies of Western Australian marine plants	Murdoch University, ±$40K p.a. 2011–2013	J Huisman (0.5) ±$40K p.a. 2011–2013
Murdoch University; Perth Zoo; Department of Environment and Heritage (SA)	Woylie Conservation Research Project	Nil	A Wayne (0.6), C Vellios (0.6), C Ward (0.6), M Maxwell (0.6)
Murdoch University Centre for Phytophthora Science and Management	Classical and molecular taxonomy and pathogenicity testing of Phytophthora species	$5K p.a. (2008–2011) $2.5K in 2011	M Stukely (0.05)
Murdoch University Centre for Phytophthora Science and Management	Molecular investigation of *Phytophthora* hybrids	$5K p.a. (2009–2011)	M Stukely (0.05)

Partnership Name i.e. CRC, Govt Dept, University, Industry, Other (sponsorships etc.)	Project	External funding and source	DEC Involvement
National Climate Change Adaptation Research Facility	Network case study: Marine biodiversity and resources network	$900K	T Holmes (0.03)
National Climate Change Adaptation Research Facility (with Murdoch University, University of Western Australia, Department of Water, CSIRO)	A risk assessment and decision framework for managing groundwater dependent ecosystems with declining water levels	$325K	A Pinder (0.1), M Pennifold (0.05)
National Climate Change Adaptation Research Facility (with Monash University, Griffith University, South Australian Research and Development Institute, Department of Environment and Resource Management (Qld), Natural Resources, Environment, the Arts and Sport (NT))	Building the climate resilience of arid zone freshwater biota: identifying and prioritising processes and scales for management	$426K	A Pinder (0.05), A Cartraud (0.05), K Quinlan (0.05)
National Heritage Trust (Kimberley Land Council)	Kimberley islands biodiversity asset identification—Phase 1 (incl. indigenous liaison and participation)	$2.7K for 2006–2011 (incl. $165k for two years)	L Gibson (0.7), N McKenzie (0.3), F Koehler (1.0), R Palmer (1.0), M Lyons (0.4), G Keighery (0.15), D Pearson (0.05), P Handasyde (0.75), V Kessner (0.75), B Muir (0.4), J Rolfe (0.05), W Caton (1.0)
National Science Foundation (US)	Systematics and Biogeography of the Inocybaceae	$19K	N Bougher (0.05)
Rio Tinto	Identification Botanist position at the Western Australian Herbarium	$114K (to December 2014)	J Hurter (1.0)
Rio Tinto Iron Ore	Seed collection zones for the Pilbara	$50K	M Byrne (0.1), S van Leeuwen (0.1), D Coates (0.1)
Rio Tinto Iron Ore (Mesa A Environmental Offsets)	Resolving the systematics and taxonomy of *Tephrosia* in Western Australia	$254K	R Butcher (1.0)
Rio Tinto Iron Ore (West Angelas Coondewanna West Environmental Offsets)	Fire-Mulga study: post burn monitoring and Tussock Grassland Survey of the Hamersley Range	Nil	N Guthrie (0.8)
Roy Hill and other Pilbara Mining Comapanies	Bilby conservation and management in the Pilbara	$350K p.a. year for 10 years	K Morris (0.01), M Dziminski (1.0)
Royal Botanical Gardens, Melbourne	Molecular assessment of morphological species of *Cortinarius* (Fungi) as used in field surveys by analysis of the ITS barcode region	$2.5K	R Robinson (0.05); DEC contribution $4K
Satterley Property Group	Factors associated with western ringtail possum (*Pseudocheirus occidentalis*)	$400K 2009–2013	P de Tores (0.5)

Partnership Name i.e. CRC, Govt Dept, University, Industry, Other (sponsorships etc.)	Project	External funding and source	DEC Involvement
	persistence within retained habitat at development sites		
Scitech Planetarium, The University of Western Australia, Science Teachers Association of Western Australia	Astronomy education	Nil	A Williams (0.05)
South Coast Natural Resource Management	DEC South Coast Region: Increasing Native habitat through protection of EPBC species and ecological communities (Dibbler recovery)	$30K in 2011–2013, Caring for Our Country	T Friend (0.05)
South Coast Natural Resource Management	Waterbird monitoring in the Lake Gore and Lake Warden wetland systems (part of State Salinity Strategy Monitoring project)	$18K in 2010–2011, via Esperance regional office	A Pinder (0.1)
Space Telescope Science Institute, USA; South African Astronomical Observatory; Institut d' Astrophysique, France; U Potsdam, Germany; University of St Andrews, Scotland; University of Tasmania	PLANET—Monitoring gravitational microlenses	Nil	R Martin (0.2), A Williams (0.25), A Verveer (0.06)
State NRM	Emergency Recovery Actions for Highest Priority Threatened Flora	$870,000	D Coates (0.05), A Cochrane (0.05); DEC Regional Services (7.0)
State NRM	Recovery of the critically endangered woylie	$250,000	A Wayne (0.6), C Vellios (0.6), C Ward (0.6), M Maxwell (0.6) DEC Regional Services (2.0)
Terrestrial Ecosystem Research Network (TERN)	Multiscale Plot Network, Ausplot Rangelands, SWATT	Nil	S van Leeuwen (0.01)
The University of Western Australia	Assessing fish communities in Marmion Marine Park	Nil	K Friedman (0.01) DEC contribution $4K
The University of Western Australia	Assessing fish communities in Shoalwater Islands Marine Park	Nil	K Friedman (0.01) A Kendrick (0.01) S Wilson (0.01) M Rule (0.05) K Bancroft (0.01) T Holmes (0.05). DEC contribution $12K
The University of Western Australia	Genetic diversity of corals in the Montebello and Barrow Islands MPAs	Nil	S Field (0.01)
The University of Western Australia	Variable Star Observations	Nil	R Martin (0.1) A Williams (0.1)
The University of Western Australia	Mode of action of phosphonate in native hosts to *Phytophthora cinnamomi*	Nil	B Shearer (0.04)
The University of Western Australia	Understanding the early	In kind from the	S Whiting (0.05)

Partnership Name i.e. CRC, Govt Dept, University, Industry, Other (sponsorships etc.)	Project	External funding and source	DEC Involvement
	offshore migration patterns of turtle hatchlings and the effects of anthropogenic light—a pilot study	University of Western Australia $24,000; Australian Institute of Marine Science $5,700; Pendoley Enviornmental Pty Ltd $5,700	
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 (0.01)
The University of Western Australia Centre of Excellence for Environmental Decisions	Susceptibility of frogs to declining rainfall in a biodiversity hotspot	Nil	M Cowan (0.02)
University of Adelaide	Wetland monitoring program—rotifer and cladoceran identifications	Nil	A Pinder (0.05), D Cale (0.05) DEC contribution $400
University of California, Berkeley and Lawrence Hall of Science	Hands on Universe—internet telescope	$1K	R Martin (0.01), A Verveer (0.05)
University of Michigan Department of Ecology & Evolutionary Biology	Contemporary ecological factors and historical evolutionary factors influencing the distribution and abundance of arid-zone reptile species in space and time	Nil	M Cowan (0.01)
University of Nebraska, Omaha USA	Fire ecology of hummock grasslands	Nil	B Ward (0.1)
University of Tasmania	Understanding the health effects of landscape burning and biomass smoke in Australian towns and cities	Nil	L McCaw (0.05) DEC contribution $10K for three years
WA Naturalists Club	PUBF: Perth Urban Bushland Fungi project	$10K	Bougher (0.05), R Hart (0.2),
Walpole - Nornalup National Parks Association; Walpole Wilderness Eco-Cruises	The impact of wildfire on invertebrate communities in old growth forests	Nuyts Wilderness Community Trust funds annual collection curation	P Van Heurck (0.1), T Middleton (0.1); WNNPA volunteers
Warren Catchments Council	Using well managed habitat to rescue woylies from the brink of extinction	$70K CFOC	A Wayne (0.6), C Velios (0.6), C Ward (0.6), M Maxwell (0.6)
Western Australian Museum	Kimberley island biodiversity asset identification	Nil	L Gibson (0.7), R Palmer (1.0)
Western Australian Museum	NatureMap—data sharing and joint custodianship	Nil	P Gioia (0.45)
Western Australian Museum	Pilbara Biological Survey	$500K in-kind, 2005–2011	N McKenzie (0.3)

Partnership Name i.e. CRC, Govt Dept, University, Industry, Other (sponsorships etc.)	Project	External funding and source	DEC Involvement
Woodside Energy	Taxonomic studies on Burrup Flora	$120K	R Butcher (0.25), K Shepherd (0.25), J Wege (0.25)

SUMMARY OF RESEARCH PROJECTS BY DEC, NRM, IBRA/IMCRA REGIONS

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
BIODIVERSITY AND CLIMATE CHANGE UNIT: COLIN YATES				
Midwest, South Coast, Swan, Warren, Wheatbelt	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Warren, Esperance Plains	Wheatbelt, Northern Agricultural, South Coast, South West, Swan	Temperature thresholds for recruitment in south-west Western Australian flora	45
South Coast	Esperance Plains, Warren	South Coast	Comparison of plant canker pathogen impact and climatic variables in Proteaceae on the south coast of Western Australia and evaluation of selected fungicides as a management tool for canker control in the Declared Rare Flora *Banksia verticillata* and *Lambertia orbifolia*	46
South Coast, Warren, Wheatbelt	Esperance Plains, Mallee, Jarrah Forest, Avon Wheatbelt, Warren	Wheatbelt, South Coast, South West	Protecting the safe havens: will granite outcrop environments serve as refuges for flora threatened by climate change?	47
Goldfields, Warren, Wheatbelt	Coolgardie, Mallee, Avon Wheatbelt, Warren	Wheatbelt, Rangelands, South Coast	Climate-resilient vegetation of multi-use landscapes: exploiting genetic variability in widespread species	48
Midwest, South Coast, Swan, Warren, Wheatbelt	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Warren, Esperance Plains	Wheatbelt, Northern Agricultural, South Coast, South West, Swan	Collaborative research on biodiversity and climate change in megadiverse ecosystems	50
Midwest	Geraldton Sandplains	Northern Agricultural	Climate change risks for biodiversity and ecosystem function in species-rich shrublands	50
BIOGEOGRAPHY PROGRAM: STEPHEN VAN LEEUWEN				
All	All	All	Ecomorphological clues to community structure; bat echolocation studies	52
South West, Swan	Swan Coastal Plain	South West, Swan	Floristic survey of the remnant heaths and woodlands of the Swan Coastal Plain	53
Pilbara	Pilbara	Rangelands	Pilbara regional biological survey	54
Kimberley	Dampierland, Northern Kimberley, Victoria Bonaparte	Rangelands	Kimberley islands biological survey	55
Goldfields, Midwest	Coolgardie, Murchison, Gascoyne, Avon Wheatbelt, Yalgoo	Northern Agricultural, Rangelands	Floristic surveys of the banded iron formation (BIF) and greenstone ranges of the Yilgarn	56

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
South Coast	Esperance Plains, Mallee	South Coast	Biological survey of the Ravensthorpe Range	56
Pilbara	Pilbara	Rangelands	Short-range endemism of ground-dwelling invertebrates in the central Pilbara	57
All	All	All	Development of ethically acceptable techniques for invertebrate wet-pit trapping	58
Goldfields, Midwest	Murchison	Rangelands	Northern Goldfields Calcrete Survey: Phase 1	59
All	All	All	Western Australian wetland fauna surveys	59
All	All	All	Western Australian flora surveys	60
FAUNA CONSERVATION PROGRAM: KEITH MORRIS				
Goldfields, Swan	Coolgardie, Swan Coastal Plain	Rangelands, Swan	Conservation of Western Australian butterflies	62
South Coast, South West, Swan, Warren, Wheatbelt	Esperance Plains, Mallee, Jarrah Forest, Avon Wheatbelt	Wheatbelt, South Coast, South West, Swan	Implementation of the recovery plan for the chuditch (*Dasyurus geoffroii*)	63
South Coast, Swan, Warren, Wheatbelt	Mallee, Jarrah Forest, Swan Coastal Plain, Avon Wheatbelt, Warren, Yalgoo	Wheatbelt, South Coast, South West, Swan	Factors affecting establishment in the numbat (*Myrmecobius fasciatus*) recovery plan	63
Wheatbelt	Avon Wheatbelt	Wheatbelt, South West	An assessment of the effect of fox control on red-tailed phascogale (*Phascogale calura*) populations	64
Midwest	Swan Coastal Plain	Northern Agricultural	Ecology and conservation of threatened pythons in Western Australia	65
Midwest	Carnarvon, Geraldton Sandplains	Wheatbelt, Rangelands	Genetics and ecology of the western barred bandicoot (*Perameles bougainville*)	66
Midwest, South Coast	Esperance Plains, Geraldton Sandplains, Jarrah Forest, Swan Coastal Plain	Northern Agricultural, South Coast	Dibbler (*Parantechinus apicalis*) recovery plan	66
South Coast	Jarrah Forest	South Coast	Gilbert's potoroo (*Potorous gilbertii*) recovery plan	67
Midwest	Swan Coastal Plain	Northern Agricultural	Implementation of the Lancelin Island skink recovery plan	68
Goldfields, South West, Warren, Wheatbelt	Coolgardie, Jarrah Forest, Avon Wheatbelt, Warren	Wheatbelt, Rangelands, South West	Probait trials: Phase 2	69
Wheatbelt	Avon Wheatbelt	Wheatbelt, South West	Return to Dryandra	69
Goldfields, Midwest	Carnarvon, Murchison, Gascoyne, Gibson Desert	Rangelands	Development of effective broad-scale aerial baiting strategies for the control of feral cats	70

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
Kimberley	Northern Kimberley, Ord Victoria Plain, Central Kimberley, Victoria Bonaparte	Rangelands	Impact of cane toads on biodiversity in the Kimberley	71
South West, Swan	Jarrah Forest	Wheatbelt, South West, Swan	The importance of fox, cat and native predator interactions to sustained fauna recovery in the northern jarrah forest—is there a mesopredator release effect?	72
South West, Swan	Swan Coastal Plain	South West	Translocation outcomes and monitoring of naturally occurring populations of the western ringtail possum (*Pseudocheirus occidentalis*)	73
Wheatbelt	Avon Wheatbelt	Wheatbelt, South West	Sustained fauna recovery in a fragmented landscape (Dryandra Woodland and Tutanning Nature Reserve)	74
Wheatbelt	Mallee	Wheatbelt	Factors affecting fauna recovery in the Wheatbelt–Lake Magenta and Dunn Rock Nature Reserves	75
Warren	Jarrah Forest	South West	Identifying the cause(s) of the recent declines of woylies in south-west Western Australia	75
Midwest	Avon Wheatbelt, Yalgoo	Northern Agricultural, Rangelands	Sustained introduced predator control in the rangelands	76
Goldfields, Swan	Coolgardie, Swan Coastal Plain	Rangelands, Swan	Conservation of the graceful sun-moth	77
Pilbara	Pilbara	Rangelands	Ecology and management of the northern quoll in the Pilbara	78
South Coast, Warren	Esperance Plains, Jarrah Forest, Warren	South Coast, South West	Conservation of south coast threatened birds	79
Pilbara, Swan	Pilbara, Swan Coastal Plain	Rangelands, Swan	Genetic approaches for evaluating the contribution of the reserve system to fauna conservation	79
Kimberley, Pilbara	Dampierland, Northern Kimberley, Pilbara, Central Kimberley	Rangelands	Genetic assessment for conservation of rare and threatened fauna	80
FLORA CONSERVATION AND HERBARIUM PROGRAM: DAVID COATES				
All	All	All	Taxonomic review and conservation status of the members of the Myrtaceae tribe Chamelaucieae and miscellaneous other Western Australian plant groups	82
South Coast, South West	Esperance Plains, Jarrah Forest, Swan Coastal Plain	Wheatbelt, South Coast, South West, Swan	Integrated strategies for the control of *Phytophthora cinnamomi* using phosphite	83
Goldfields, Midwest, South Coast, Swan,	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Mallee,	Wheatbelt, Northern Agricultural,	Genetics and biosystematics for the conservation, circumscription and management of the Western Australian flora	83

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
Wheatbelt	Coolgardie, Murchison, Yalgoo, Esperance Plains	South Coast, South West, Swan		
All	All	All	Australian wattle identification	85
All	All	All	Seed biology, seedbank dynamics and collection and storage of seed of rare and threatened Western Australian taxa	86
Midwest, South Coast, South West, Swan, Warren, Wheatbelt	Esperance Plains, Geraldton Sandplains, Jarrah Forest, Swan Coastal Plain, Avon Wheatbelt, Warren	Wheatbelt, South Coast, South West, Swan	Susceptibility of rare and endangered flora to *Phytophthora*	87
Goldfields, Midwest, South Coast, South West, Swan, Wheatbelt	Esperance Plains, Jarrah Forest, Avon Wheatbelt	Wheatbelt, Northern Agricultural, Rangelands, South Coast, South West, Swan	The population ecology of critically endangered flora	88
Midwest, South Coast, South West, Swan, Warren, Wheatbelt	Esperance Plains, Mallee, Jarrah Forest, Swan Coastal Plain, Avon Wheatbelt	Wheatbelt, Northern Agricultural, Rangelands, South Coast, South West, Swan	Mating system variation, genetic diversity and viability of small fragmented populations of threatened flora, and other key plants of conservation importance	89
Midwest, South Coast, South West, Wheatbelt	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Coolgardie, Warren, Esperance Plains	Wheatbelt, Northern Agricultural, South Coast, South West, Swan	Translocation of critically endangered plants	90
Wheatbelt	Swan Coastal Plain, Avon Wheatbelt	Wheatbelt, Northern Agricultural, South Coast, Swan	Genetic and ecological viability of plant populations in remnant vegetation	91
All	All	All	Conservation status and systematics of Western Australian *Acacia*	92
Pilbara	Pilbara	Rangelands	Wattles of the Pilbara	93
All	All	All	Development of interactive identification platforms and content	93
All	All	All	Taxonomic resolution and description of new plant species, particularly Priority Flora from those areas subject to mining in Western Australia	94
South Coast, South West	Esperance Plains, Jarrah Forest, Swan Coastal Plain	Wheatbelt, South Coast, South West, Swan	An investigation of the epidemiology and use of novel phosphite application techniques in *Phytophthora cinnamomi* infestations in the national parks of the South Coast Region of Western Australia	95
Kimberley,	Geraldton Sandplains,	Northern	The Western Australian marine benthic algae	96

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
Midwest, Pilbara, South Coast, South West, Swan, Warren	Swan Coastal Plain, Jarrah Forest, Central Kimberley, Victoria Bonaparte, Warren, Dampierland, Northern Kimberley, Esperance Plains	Agricultural, Rangelands, South Coast, South West, Swan	online and an interactive key to the genera of Australian marine benthic algae	
Kimberley, Pilbara, South Coast, South West, Swan, Warren	Geraldton Sandplains, Swan Coastal Plain, Jarrah Forest, Central Kimberley, Victoria Bonaparte, Warren, Dampierland, Northern Kimberley, Esperance Plains, Gascoyne	Northern Agricultural, Rangelands, South Coast, South West, Swan	Taxonomic review and floristic studies of the benthic marine algae of north-western Western Australian and floristic surveys of Western Australian marine benthic algae	97
All	All	All	Systematics of the triggerplant genus *Stylidium*	98
All	All	All	Taxonomy of selected families including legumes, grasses and lilies	99
Kimberley, Pilbara	Gibson Desert, Great Sandy Desert, Carnarvon, Little Sandy Desert, Central Kimberley, Victoria Bonaparte, Central Ranges, Dampierland, Northern Kimberley, Ord Victoria Plain, Gascoyne	Northern Agricultural, Rangelands	Resolving the systematics and taxonomy of *Tephrosia* in Western Australia	100
All	All	All	Taxonomic studies in selected families, including Asteraceae, Celastraceae, Malvaceae, Proteaceae	101
Midwest	Yalgoo	Northern Agricultural	Assessment of genetic diversity, key population processes and evolutionary relationships in the banded iron formation endemic *Acacia woodmaniorum* and its close relatives	102
Midwest, South Coast, Swan, Wheatbelt	Coolgardie, Esperance Plains, Mallee, Geraldton Sandplains, Swan Coastal Plain, Avon Wheatbelt	Wheatbelt, Northern Agricultural, Rangelands, South Coast, South West, Swan	Taxonomic studies on native and naturalised plants of Western Australia arising from biological survey	103
South Coast, South West, Swan, Warren, Wheatbelt	Esperance Plains, Geraldton Sandplains, Jarrah Forest, Swan Coastal Plain, Avon Wheatbelt, Warren	Northern Agricultural, South Coast, South West, Swan	Strategic taxonomic studies in families including Epacridaceae, Rafflesiaceae, Rhamnaceae and Dilleniaceae	104
All	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Warren, Esperance Plains	All	Taxonomy of undescribed taxa in the Ericaceae subfamily Styphelioideae, with an emphasis on those of conservation concern	105
All	All	All	FloraBase and biodiversity informatics at the Western Australian Herbarium	105
All	All	All	Herbarium collections management	107
All	All	All	The Western Australian Herbarium‘s specimen database	108

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
All	All	All	The Western Australian Plant Census and Australian Plant Census	109
Midwest, South Coast, South West, Swan, Warren, Wheatbelt	Esperance Plains, Geraldton Sandplains, Jarrah Forest, Swan Coastal Plain, Avon Wheatbelt, Warren	Wheatbelt, Northern Agricultural, South Coast, South West, Swan	Vegetation Health Service	110
Midwest, South Coast, South West, Swan, Warren, Wheatbelt	Esperance Plains, Jarrah Forest, Swan Coastal Plain, Avon Wheatbelt, Warren	Wheatbelt, South Coast, South West, Swan	Ecophysiology of rare flora restricted to shallow-soil communities	112
South Coast	Esperance Plains, Warren	South Coast	Effects of pre-treatments, microhabitats and on-site management in the translocation success of threatened plant species: an ecophysiological approach	113
All	All	All	Strategic taxonomic studies in families including Amaranthaceae and Fabaceae (*Ptilotus, Gomphrena, Swainsona*) and other plant groups	113
Goldfields, Midwest, Pilbara	Gibson Desert, Great Sandy Desert, Great Victoria Desert, Tanami, Little Sandy Desert, Coolgardie, Central Ranges, Murchison, Yalgoo, Nullarbor, Pilbara, Gascoyne	Rangelands	Understanding mulga	114
All	All	All	Biosystematics of fungi for conservation and restoration of Western Australia‘s biota	115
LANDSCAPE CONSERVATION PROGRAM: LACHIE MCCAW				
Warren	Jarrah Forest	South West	Effects of timber harvesting on terrestrial vertebrates in medium-rainfall jarrah forest	117
Goldfields, South Coast, Wheatbelt	Coolgardie, Esperance Plains, Mallee	Rangelands, South Coast	Fire-induced mosaics in semi-arid shrublands and woodlands	118
South West, Swan	Jarrah Forest	South West, Swan	Effect of stand density and fertilising on seed-fall. Exp B. Establishment of jarrah (*Eucalyptus marginata*) in shelterwood areas and on dieback ‗graveyard‘ sites	118
South West, Warren	Jarrah Forest	South West, Swan	Characteristics of hollow-bearing jarrah (*Eucalyptus marginata*) and marri (*Corymbia calophylla*) trees and coarse woody debris (CWD), their use by selected species of fauna, and the effect of logging-and-burning of jarrah forest on them	119
South West	Jarrah Forest	South West	Control of jarrah leafminer: selective retention of jarrah leafminer resistant trees and ground coppice in a demonstration forest plot	120
South West,	Jarrah Forest	South West	Monitoring long-term effects of various fire	121

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
Warren			regimes on species richness and composition of southern jarrah forest understorey	
Warren	Warren	South West	Increasing productivity of karri regrowth stands by thinning and fertilising	121
Warren	Warren	South West	Espacement effects on the development and form of regrowth karri stands	122
Warren	Jarrah Forest, Warren	South West	Long-term monitoring of impact of timber harvesting on bird populations in south-west forests	122
South West, Swan, Warren	Jarrah Forest, Warren	South Coast, South West, Swan	Project Vesta—prediction of high intensity fire behaviour in dry eucalypt forest	123
Warren	Warren	South West	*Armillaria* spread in karri	124
Goldfields, Midwest, South Coast, South West, Warren, Wheatbelt	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Mallee, Coolgardie, Murchison, Esperance Plains	Wheatbelt, Northern Agricultural, Rangelands, South Coast, South West	Genetic analysis for the development of vegetation services and sustainable environmental management	124
Warren	Warren	South West	The effect of wildfire on forest fungi	126
Midwest, South Coast, South West, Swan, Warren, Wheatbelt	Esperance Plains, Mallee, Geraldton Sandplains, Jarrah Forest, Avon Wheatbelt	Wheatbelt, Northern Agricultural, South Coast, South West	State Salinity Strategy wetland monitoring	126
South West	Swan Coastal Plain	South West	Management of the Vasse–Wonnerup wetlands	128
South West, Warren	Jarrah Forest, Warren	South West, Swan	Evaluation of key soil indicators of sustainability in Australian mediterranean forests (Indicators 4.1d, 4.1e)	128
Swan	Jarrah Forest	South West, Swan	Hydrological response to timber harvesting and associated silviculture in the intermediate rainfall zone of the northern jarrah forest	129
Swan	Jarrah Forest	Swan	Landscape and fire management interactions and their effects on distribution of invertebrate biodiversity	130
Warren	Warren	South Coast, South West	The impact of wildfire in old growth forest of the Walpole–Nornalup National Park on short-range endemic invertebrates and their forest floor communities	131
Goldfields	Murchison, Gascoyne	Rangelands	Project Rangelands Restoration: Developing sustainable management systems for the conservation of biodiversity at the landscape scale in rangelands of the Murchison and Gascoyne bioregions—managing fire and introduced predators (see also Rangelands Restoration—reintroduction of native animals to Lorna Glen in Fauna Conservation Program section of this report)	132
Midwest, South	Esperance Plains,	Wheatbelt,	Management of environmental risk in perennial	133

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
Coast, Wheatbelt	Geraldton Sandplains, Avon Wheatbelt	Northern Agricultural, South Coast	land use systems	
Warren	Jarrah Forest	South West	Burning for biodiversity: Walpole fine-grain mosaic burning trial	135
Warren	Warren	South Coast, South West	Monitoring post-fire effects from the 2001 Nuyts wildfire	135
South West, Swan, Warren	Jarrah Forest, Warren	South Coast, South West, Swan	Monitoring stream biodiversity (KPI 20 of the Forest Management Plan)	136
South West, Swan, Warren	Jarrah Forest, Warren	South West, Swan	FORESTCHECK—integrated site-based monitoring of the effects of timber harvesting and silviculture in the jarrah forest	137
South West, Warren	Jarrah Forest	Wheatbelt, South West	Identification of seed collection zones for rehabilitation	138
Goldfields, Kimberley, Warren, Wheatbelt	Gascoyne, Jarrah Forest, Central Kimberley, Victoria Bonaparte	Wheatbelt, Rangelands, South West	Bushfire Cooperative Research Centre Project 1.4: Improved methods for the assessment and prediction of grassland curing	139
Kimberley	Northern Kimberley	Rangelands	Fire regimes and biodiversity decline in the Kimberley	139
South West, Swan	Jarrah Forest	South West, Swan	Aspects of dieback behaviour relevant to the formulation of jarrah silviculture guidelines	140
South Coast, Wheatbelt	Esperance Plains, Mallee, Avon Wheatbelt	Wheatbelt, Rangelands, South Coast	Fire, fragmentation, weeds and the conservation of plant diversity in Wheatbelt nature reserves	142
Swan	Jarrah Forest	Swan	Monitoring the northern extent of jarrah leafminer outbreak	143
Goldfields, South Coast, Wheatbelt	Coolgardie, Mallee, Avon Wheatbelt, Yalgoo	Wheatbelt, Rangelands	Fire regimes and impacts in transitional woodlands and shrublands	143
South West, Swan, Warren	Esperance Plains, Mallee, Jarrah Forest, Swan Coastal Plain, Warren	South Coast, South West, Swan	Management of invertebrate pests in forests of south-west Western Australia	144
Kimberley	Northern Kimberley	Rangelands	North Kimberley Landscape Conservation Initiative—Monitoring and Evaluation	145
MARINE SCIENCE PROGRAM: CHRIS SIMPSON				
Kimberley, Midwest, Pilbara	Carnarvon, Geraldton Sandplains, Northern Kimberley, Pilbara	Rangelands	Conservation of marine turtles in Western Australia	147
Pilbara	Pilbara (nearshore), Pilbara (offshore)	Rangelands	Establishment of a long-term monitoring program for the proposed Dampier Archipelago Marine Park	148
Swan	Central West Coast	Perth	Spatial and temporal patterns in the structure of	149

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
			intertidal rocky platform communities of the Shoalwater Islands and Marmion Marine Parks	
Pilbara	Ningaloo	Rangelands	Interactive effects of fishing and climate change on coral reef fish populations	150
Warren	WA South Coast	South Coast	Spatial and temporal patterns in benthic invertebrate communities of the Walpole and Nornalup Inlets Marine Park	151
All	All	All	Survey of the distribution and abundance of New Zealand fur seals in Western Australia	152
Pilbara	Ningaloo	Rangelands	Effects of the Gorgon Project dredging program on the marine biodiversity of the Montebellos/Barrow Islands Marine Protected Areas	153
All	All	All	Comparison of underwater visual census and diver-operated video methods for assessing fish community condition in tropical and temperate coastal waters of Western Australia	154
Midwest	Shark Bay	Rangelands	Spatial variation in the functional morphology of mangroves in the Shark Bay World Heritage Area	155
Pilbara	Ningaloo	Rangelands	Regional-scale coral bleaching on Western Australian reefs	156
Pilbara	Ningaloo	Rangelands	WAMSI 1 Node 3: Science administration, coordination and integration	157
Kimberley, Pilbara	King Sound, Kimberley, Oceanic Shoals, Bonaparte Gulf, Northwest Shelf, Cambridge Bonaparte, Eighty Mile Beach, Canning	Rangelands	WAMSI 2: Kimberley Marine Research Program	158
Kimberley, Pilbara	Northwest Shelf	Rangelands	North West Shelf Flatback Turtle Conservation Program Strategic Plan	159
All	All	All	Development of a strategic marine research plan for the Western Australian Department of Environment and Conservation: 2010–2015	160
Pilbara	Pilbara (nearshore), Pilbara (offshore)	Rangelands	Review, assess and summarise historical data relevant to the management of the proposed Dampier Archipelago Marine Park and Regnard Marine Management Area	161
All	All	All	The Western Australian Marine Monitoring Program (WAMMP)	162
All	All	All	WAMMP Sub-project 1: Asset knowledge review and standard operating protocol documentation	163
All	All	All	WAMMP Sub-project 2: Historical time-series development	164
All	All	All	WAMMP Sub-project 3: 'Fit to park'	165
All	All	All	WAMMP Sub-project 4: MPRA/DEC audit	166

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
			support and management effectiveness reporting	
All	All	All	WAMMP Sub-project 5: Community participation and liaison	167
All	All	All	WAMMP Sub-project 6: Marine information management system	168
SCIENCE APPLICATIONS UNIT: PAUL GIOIA				
All	All	All	Plant species richness and endemism within the south-western Australian Floristic Region	169
All	All	All	Online GIS biodiversity mapping (NatureMap)	170
All	All	All	Provision of authoritative names of Western Australian taxa	170

RESEARCH ACTIVITIES

BIODIVERSITY AND CLIMATE CHANGE UNIT

UNIT MANAGER: COLIN YATES

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

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

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

Temperature thresholds for recruitment in south-west Western Australian flora

SPP 2010-003

Team members

A Cochrane

Context

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

Aims

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

Summary of progress and main findings

- Continued investigations of temperature profiles for seed germination in populations of four *Banksia* species sampled from across an east-west climate gradient.
- Completed a common garden experiment investigating the effects of increased temperature and altered rainfall on seedling emergence, early growth and survival in populations of four *Banksia* species sampled from across an east-west climate gradient.
- Prepared an advanced draft of a manuscript reviewing the evidence for population variation in seed germination and seedling traits across climate gradients.

Management implications

Development of a seed-based framework for assessing seed viability under environmental change will assist in restoration. Incorporation of seed biology into threatened species reintroductions will improve recovery success.

Future directions (next 12 to 18 months)

- Determine the influence of projected climate change on seed and seedling traits in species, population and range dynamics along an east-west climate gradient in Western Australia.
- Undertake a glasshouse irrigation/warming trial and a laboratory moisture stress experiment.
- Submit paper on *Banksia* germination temperature thresholds to a scientific journal.
- Submit review paper on population variation in seed and seedling traits across climate gradients to a scientific journal.
- Begin analysis of the common garden climate manipulation experiment and prepare a draft manuscript describing the effects of treatments on seedling emergence.

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

SPP 2010-004

Team members

C Crane, S Barrett, B Shearer, C Dunne

Context

The contribution of canker fungi to stem and branch death in southern Western Australia has largely been ignored. Canker pathogens, both primary and facultative, constantly take advantage of changes in environment and host susceptibility, and will provide direct measures of the mechanisms of climate change fluctuation on species distribution.

Aims

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

Summary of progress and main findings

- A further 10 climate data-logging stations were added to the network of 20 previously installed.
- A resurvey of base-line transects occurred.
- One new genus of causal canker fungus has been identified and is being described.

- A further three more fungicides have been tested *in vitro* and *in vivo*, with two identified as being useful for protection of Declared Rare Flora from canker lesion development.
- Growth rates/temperature have been determined for the three main canker fungi.

Management implications

- Preliminary recommendations are now available for fungicide treatments to reduce the rate of canker lesion development within the translocated proteaceous Declared Rare Flora populations.
- Some emerging endemic pathogens are flourishing under changing environmental conditions. These increases in disease need to be considered in both biodiversity and forestry management, as well as rcovery plans at the species and community level.

Future directions (next 12 to 18 months)

- Repeat rating and subsequent analysis of transect data in November 2012.
- Determine the influence of climate on the incidence and severity of canker impact in proteaceous species in south-western Australia.
- Description of *Cirrhiluteous shearii*, a new genus and species of canker pathogen in Cryphonectriaceae, in conjunction with Murdoch University.

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

SPP 2011-011

Team members

C Yates, M Byrne, S Battilana, G Wardell-Johnson (Curtin University), L Mucina (Curtin University), K van Niel (University of Western Australia), S Hopper (Royal Botanic Gardens Kew), S Franklin (University of Saskatchewan)

Context

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

Aims

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

Summary of progress and main findings

- Completed plant identifications for 150 vegetation plots across environmental gradients on five GOs.
- Established 300 vegetation plots across environmental gradients on 10 GOs.

- Completed measurements of local climate and micro-climate on five focal GOs across environmental gradients.
- Continued modelling of LiDAR and other multi-spectral remote sensed data for 28 GO field sites.
- Completed study of composition and phenology of GO herbfields in relation to micro-environment.
- Completed survey of the rare GO endemic plant *Ornduffia calthifolia* and associated micro-environment variables.
- Completed genotyping and data analysis for phylogeographic studies on two common GO endemic plant species, *Kunzea pulchella* and *Stypandra glauca*.
- Completed genotyping for population genetic studies on *Kunzea pulchella* and *Stypandra glauca* and data analysis is underway.
- Continued databasing Hopper's GO species occurrence records.
- Published a review manuscript 'Refugia: identifying and understanding safe havens for biodiversity under climate change' in *Global Ecology and Biogeography*.
- Published opinion manuscript 'Refugia: keys to climate change management' in *Global Change Biology*.

Management implications

By identifying areas that can act as refugia under projected climate change, adaptation and conservation activities can be focused where they will provide greatest benefit.

Future directions (next 12 to 18 months)

- Complete identification of plant species records from 300 vegetation plots across 10 GOs.
- Integrate plant species records from 450 plots across 15 GOs in a database.
- Continue modeling LiDAR and multi-spectral remote sensed data.
- Model the influence of climate, micro-climate and soil depth on GO plant community composition.
- Model the influence of micro-climate and soil depth on the composition and phenology of GO herbfields.
- Model the influence of micro-climate and soil depth on the distribution of *Ornduffia calthifolia*.
- Continue entry of Hopper's GO data and check database.
- Complete data analysis for population genetic studies on *Kunzea pulchella* and *Stypandra glauca*.
- Write journal papers on ecological and genetic evidence for grantite outcrops as historical and future climate change refugia.

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

SPP 2012-002

Team members

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

Context

Multi-million dollar investments in the restoration of Australia's degraded and fragmented multi-use landscapes currently take little account of climate change. Until recently there has been a strong focus on maintaining local genetic patterns for optimal restoration. In a changing climate this paradigm may

no longer be relevant and a new framework is urgently needed. The proposed project will deliver such a framework by undertaking pioneering research and development at the interface between molecular genetics, plant physiology and climate adaptation. Specifically, it will test hypotheses of adaptation in widespread eucalypt species, by investigating correlations between key physiological traits and genetic signatures of adaptation across climatic gradients utilising recent advances in eucalypt genomics. Addressing this question will ensure optimal, climate-resilient outcomes for Australia-wide investment in ecological restoration, offering a novel solution to ecosystem adaptation in changing environments.

Aims

The project will test the following alternative hypotheses:

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

Summary of progress and main findings

- Information was compiled on suitable sampling options and designs, including tree species characteristics, climatic and geographic distributions, and the availability of intact wild populations and of existing provenance-trial plantations.
- The end-user reference group was engaged in discussion on species selection and field design. Priorities in the design process included selection of species relevant to revegetation, and making use of older provenance trial plantations in order to better assess long term establishment success rates.
- Two study species were selected: *Eucalyptus salubris* in Western Australia and *E. tricarpa* in Victoria. Sampling schemes consisted of nine populations per species across a climatic gradient, with three populations at each of the climatic extremes, and three populations of intermediate climate. For *E. tricarpa,* ecophysiology was also sampled for the same nine populations from within two existing provenance trials, one located at each end of the climate gradient.
- All field sampling was completed for both species for genetic analysis, ecophysiological analysis and soil analysis.

Management implications

Landscape-scale restoration of over-cleared, multi-use landscapes can only be achieved through revegetation. This typically includes planting of indigenous native plant species, sometimes in combination with native or exotic perennials for production or carbon sequestration. In each of these cases investments will be wasted and goals will not be achieved if plantings are not resilient to climate change. One of the few significant avenues for increasing the success of landscape-scale restoration is to increase climate resilience through use of appropriate genetic stock. Determination of patterns of adaptive variation in widespread eucalypts of eastern and western Australian agricultural landscapes will enable development of new approaches to sourcing genetic stock for climate-resilient revegetation that is applicable at the national scale.

Future directions (next 12 to 18 months)

- Genetic analysis will be undertaken for *E. salubris* and *E. tricarpa.*
- Ecophysiology analysis will be undertaken for *E. salubris* and *E. tricarpa.*
- Integration of genetic and ecophysiology data for identification of adaptation to climate.

Collaborative research on biodiversity and climate change in megadiverse ecosystems

SPP 2012-020

Team members

C Yates, G Midgley (South African National Biodiversity Institute), D Le Maitre (CSIR, South Africa), D Richardson (University of Stellenbosch), J Scott (CSIRO Climate Change Adaptation Flagship Australia), B Webber (CSIRO Climate Change Adaptation Flagship Australia)

Context

The south-west Australian Floristic Region and Cape Floristic Region of South Africa have a shared evolutionary history and many ecological characteristics that make them ideal for comparative studies investigating the impacts of climate change on biodiversity. Such studies may yield insights that might not be gained if activities were restricted to one region alone. Species and ecosystems in both regions are already under threat from a range of threatening processes, and projected warming and drying of climates is expected to place biodiversity under further stress. Tools for assessing the vulnerability of biodiversity to climate change in both regions and for informing response planning are urgently needed.

Aims

- Review methods for modelling the impacts of climate change on biodiversity and assess their suitability for application in the south-west Australian Floristic Region and Cape Floristic Region.
- Review the critical role of monitoring in detecting the impacts of climate change on biodiversity, validating model projections and measuring adaptive responses.
- Review the role of information management in science planning for climate change.

Summary of progress and main findings

Published manuscript 'Modeling horses for novel climate courses: insights from projecting potential distributions of native and alien Australian acacias with correlative and mechanistic models' in the journal *Diversity and Distributions*.

Management implications

Climate change is likely to have implications for all DEC activities including reserve design, fire management, fauna and flora translocations, disease management, and forest management.

Future directions (next 12 to 18 months)

Prepare a review paper on invasive alien species and climate change in the south-west Australian Floristic Region and Cape Floristic Region global biodiversity hotspots.

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

SPP 2012-021

Team members

C Yates, G Midgley (South African National Biodiversity Institute), N Enright (Murdoch University), R Froend (Edith Cowan University), J Fontaine (Murdoch University), A Williams (Murdoch University)

Context

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

Aims

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

Summary of progress and main findings

- Continued measurements of climate on the Eneabba sandplain.
- Completed measurements of seasonal patterns in water input, storage and distribution across the soil depth gradient.
- Completed measurements of seasonal patterns in plant water use and plant demography for two species in each of two woody plant guilds across the soil depth gradient.
- Monitored the effects of climate manipulation experiments (decresed rainfall and increased temperature) on plant demography across the soil depth gradient.

Management implications

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

Future directions (next 12 to 18 months)

- Continue ecohydrology and demographic studies.
- Monitor climate manipulation experiments.
- Model the relationship between climate, soil depth, soil water storage and plant water use for the four study species.
- Model the relationship between climate, soil depth, soil water storage and demography for the four study species.

BIOGEOGRAPHY PROGRAM

PROGRAM LEADER: STEPHEN VAN LEEUWEN

The Biogeography Program undertakes biological surveys to provide information on the biodiversity and nature conservation priorities within Western Australia. Surveys provide data on the distribution of plants and animals and enable an understanding of regional patterns in their composition and distribution.

Targeted surveys of specific regions, broad habitat types or selected plant and animal groups are also undertaken. Knowledge obtained from surveys complements the site-specific studies commissioned by other land managers, such as resource companies, and is used to provide the foundation for biodiversity planning and natural resource management across Western Australia.

These activities are aligned with the information needs of the Department of Environment and Conservation. Collaborative associations are strong with the Western Australian Museum, Australian Museum, and herbaria throughout Australia, and with universities, cooperative research centres, CSIRO and other research institutions. Partnerships also exist with traditional owners, resource companies and the environmental consulting industry.

Ecomorphological clues to community structure; bat echolocation studies

SPP 1993-028

Team members

N McKenzie, R Bullen

Context

This project underpins components of the Pilbara and Kimberley islands biodiversity surveys (SPP 2004-002 and SPP 2007-001, respectively). It extends the strategies and sampling methods used in wildlife surveys to extend knowledge of the community structuring processes (including disturbances) that affect the composition and richness of bat assemblages within Western Australia.

Aims

- Compile a dictionary of sonar signatures for automatically recording the composition of bat assemblages on survey sites.
- Develop ecomorphological and spectral measures of potential niche in bats (relate them to community structuring mechanisms and species' realised foraging niches).
- Investigate metapopulation (environmental filters, biogeographic history and observed foraging niche) and environmental factors (habitat attributes, shelter requirements and disturbances), controlling species occurrence, assemblage composition and conservation status of mammals, volant and non-volant.
- Assess conservation status of native mammal assemblages in Western Australia, and species-specific risks in the context of processes such as habitat simplification, decreasing productivity, introduced mammals, climatic trends, etc.

Summary of progress and main findings

- Paper on the assemblage of Kimberley mainland bats completed and published in *Records of the Western Australian Museum*.
- Paper published presenting a velocity-power model for Western Australian bat airframes.
- Paper published in *Australian Mammalogy* on Little Sandy Desert non-volant mammals, including their habitat relationships.
- Contributed to Environment Australia working group report on the extinction of the Christmas Island Pipistrelle.

- Paper published in *Conservation Letters* on the disappearing mammal fauna of northern Australia.

Management implications

Inclusion of information on mammal communities leads to more biodiverse surveys and better understanding of guild and faunal structure in Western Australian ecological communities, a basis for informed resource development decisions and conservation reserve design. Better understanding of distributions, energetics and nature conservation status are a basis for determining appropriate management actions and priorities.

Future directions (next 12 to 18 months)

- Finalise and submit journal paper on Western Australian bats that can use flat-plate aerodynamics.
- Finalise and submit journal paper on characteristic flight speeds in Western Australian bats.
- This project is being finalised and will be closed.

Floristic survey of the remnant heaths and woodlands of the Swan Coastal Plain

SPP 1993-038

Team members

G Keighery, OEPA

Context

The Swan Coastal Plain (SCP) 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 data from new surveys, via the Swan Coastal Plain Floristic and Reserve Survey, to relevant authorities including NGOs, local government authorities, statutory planning authorities and the Environmental Protection Authority.

Aims

Undertake studies into the classification, distribution, patterning and conservation status of vascular plant communities and taxa of the SCP at a local and regional level. This will result in the preparation of flora lists for the region and individual conservation reserves. Elucidation of taxonomy of significant flora and weeds will occur as part of this process.

Summary of progress and main findings

- Scientific paper on vascular flora of national parks on the Margaret Plateau and Leeuwin–Naturaliste Ridge was published in *Conservation Science Western Australia*.
- Analysis of vegetation and flora of the Bunbury area completed and report drafted.
- Report on Barracca Nature Reserve finalised in consultation with stakeholders.

Management implications

A better understanding of the conservation values of the area forms the basis for improved land use planning and decision making for biodiversity conservation on the SCP.

Future directions (next 12 to 18 months)

This project is being finalised and will be closed.

Pilbara regional biological survey

SPP 2004-002

Team members

N McKenzie, N Guthrie, A Burbidge, S van Leeuwen, M Lyons, A Pinder, M Langley, J Rolfe, B Durrant, N Gibson, A Markey, S Halse, P Doherty, M Harvey, B Heterick, D Blinn, N Gunawardene, E Volschenk, A Baynes, R Johnstone, T Weir

Context

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

Aims

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

Summary of progress and main findings

- The reptile and frog paper is now published online, and the paper on the original bird fauna has been refereed.
- Drafts of the original bird fauna, stygofauna, wetland aquatic flora and riparian flora papers are in preparation.
- Terrestrial flora identifications are complete, and the data matrix is being error-checked.
- Modelling of the now-compiled terrestrial zoology and aquatic biodiversity data-sets for conservation gap analyses has commenced in conjunction with CSIRO.

Management implications

- Survey information forms the basis for systematic regional nature conservation planning for conservation reserve system development, and distribution and conservation status of species (indigenous and weeds) and ecological communities.
- The survey has provided an explicit, quantitative understanding of patterns in biodiversity across the region as a regional context for environmental protection. Voucher collections have been curated, identified and lodged in state natural history collections to provide baseline information for long-term ecological monitoring of the region.
- The survey team are providing data, publications, presentations and advice on the survey‘s findings to a range of regional stakeholders, including the pastoral and mining industry, DEC region, EPA/OEPA, federal agencies (DSEWPaC) as well as the wider conservation, science and environmental consultancy communities.

Future directions (next 12 to 18 months)

- Complete and analyse terrestrial flora matrices then draft and submit the flora paper for publication.
- Submit, referee and publish the remaining papers as hardcover volume ‗Part 2‘.
- Undertake communication activities to update Pilbara communities on survey findings and outputs.

Kimberley islands biological survey

SPP 2007-001

Team members

L Gibson, M Lyons, R Palmer, D Pearson, M Cowan, G Keighery, N McKenzie, F K[illegible]r, W Caton, T Handasyde, V Kessner

Context

Archipelagos along the Kimberley coast present an opportunity to conserve intact examples of ecosystems that have been modified or affected by various threatening processes on the Kimberley mainland. Knowledge is rudimentary about island distributions of species and ecological communities, including those that are endemic to the Kimberley and those that are threatened on the mainland. Consequently, a comprehensive biological survey of the islands off the north Kimberley coast is required. This survey focuses on sampling vertebrate and selected groups of invertebrate fauna that are most likely to be affected by the cane toad as well as by changes to other mainland selection processes. It will also sample the terrestrial flora, soil and other environmental attributes that are indicators of biogeographical patterning, environmental health, and 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 susceptible to mainland threats, including cane toads, and identify the potential of islands as natural refuges.
- Provide baseline information for future ecological monitoring/evaluation/survey.
- Provide the knowledge base to underpin decisions involving conservation and development, including nature-based tourism, non-renewable resource extraction and infrastructure development.

Summary of progress and main findings

- All species by island matrices compiled for the of targeted taxonomic groups.
- Publication of four scientific papers (background/logistics, non-volant mammals, land snails and bats) and one further paper under review (birds) in a dedicated edition of the Records of the Western Australian Museum (WAM), Supplement 81 (available online via WAM website).
- A further five papers (reptiles, plants, frogs, Traditional Owner perspective and synthesis) in advanced draft form.
- Major taxonomic revision on camaenid land snails published in *Malacologia*. Paper on island non-camaenid land snails published in the *Records of the Western Australian Museum*.
- Paper on Kimberley clawless geckos (*Crenadactylus*) published in *Wildlife Research* and *LANDSCOPE*.
- Presentation on the survey to the Environmental Protection Authority.

Management implications

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

Future directions (next 12 to 18 months)

- Complete and submit remaining draft papers to the *Records of the Western Australian Museum*, *Supplement*.
- Production and publication of the hard back volume.

- All data made available via NatureMap.
- Continue knowledge transfer activities including presentations to community groups.

Floristic surveys of the banded iron formation (BIF) and greenstone ranges of the Yilgarn

SPP 2007-005

Team members

N Gibson, R Meissner, R Coppen

Context

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

Aims

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

Summary of progress and main findings

- Last six papers on floristic patterns of BIF ranges published in *Conservation Science Western Australia*.
- Three papers on greenstone range surveys in press, and final three papers on greenstone range surveys drafted.
- Factsheets for 1,500 BIF and greenstone quadrats have been updated and uploaded onto NatureMap.
- Paper on meta-analysis of the complete BIF dataset outlining extremely high beta-diversity in the ranges and identifying two hotspot of specialist BIF taxa has been published.
- Paper on overview of BIF surveys currently in press.

Management implications

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

Future directions (next 12 to 18 months)

Publication of the last three greenstone surveys.

Biological survey of the Ravensthorpe Range

SPP 2007-006

Team members

N Gibson

Context

The biodiversity values of the Ravensthorpe Range, an area highly prospective for mineral exploration and mining, are poorly documented and understood. The Range is known for possessing high numbers of both threatened and/or locally endemic plant species and distinctive and/or threatened ecological communities. Recent and historical resource developments on the Range and in the near vicinity have had significant threatened flora and vegetation management issues. This project‘s principal aims are to: acquire additional knowledge on the floristics of the Ravensthorpe Range; to provide a comprehensive dataset, from site base plots, on the distribution of species and floristic communities

across the range; and to investigate the relationship between the floristic communities and mapped vegetation units.

Aims

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

Summary of progress and main findings

- Paper on Ravensthorpe Range vegetation communities accepted for publication.
- Paper on correlation between floristic communities and vegetation mapping currently in review.

Management implications

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

Future directions (next 12 to 18 months)

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

Short-range endemism of ground-dwelling invertebrates in the central Pilbara

SPP 2009-012

Team members

B Durrant

Context

Short-range endemic (SRE) invertebrates have been a focus of environmental impact assessments (EIAs) for the past decade. This focus has provided an insight into the occurrence of SRE taxa throughout the state and in so doing has highlighted considerable deficiencies in our understanding of this biota. In particular, our understanding of the habitats to which these biota are restricted is poor. This lack of understanding impacts directly on two aspects of SRE surveys: site selection and risk assessment. This project will assist resource development companies and their consultants in determining suitable survey protocols for targeted biological surveys that are designed to document the presence of SRE taxa and inform the environmental approvals process. This project will also assist in determining the significance of isolated habitat patches and provide greater confidence for decisions made during risk assessments and the environmental impacts approval process.

Aims

- Determine which characteristics define the most common SRE habitats in the Central Pilbara.
- Provide quantitative data to determine habitats that are unlikely to contain SRE taxa.
- Determine what distance and/or landscape characteristics represent significant barriers to dispersal of SRE taxa.

Summary of progress and main findings

- Completed habitat analysis and identification of all specimens.
- Completed data analysis.
- Report to BHP Billiton prepared.

Management implications

The data and knowledge gained will be used by industry and regulators (DEC, OEPA) as part of the environmental impact assessments process. An increased understanding will also inform regional land managers about the significance of particular habitats and SRE taxa, and the environmental factors that can influence their distribution.

Future directions (next 12 to 18 months)

This project is now completed.

Development of ethically acceptable techniques for invertebrate wet-pit trapping

SPP 2010-005

Team members

M Cowan, N Guthrie, T Oldfield (Consultant Vet), D Harris (WA ChemCentre), K Ho (WA ChemCentre), B Mullins (Curtin University)

Context

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

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

Aims

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

Summary of progress and main findings

- Approval has been given by DEC's Animal Ethics Committee (AEC) to field trial potential chemical solutions for bias in captures of both target and non-target fauna as well as to examine preservation characteristics and longevity of solutions under field conditions.
- Reporting was concluded for the laboratory trials conducted by Western Australian ChemCentre.
- The only alternatives to glycol based solutions identified that have the potential to meet the required objectives of the project have been oil-based solutions over various concentrations of ethanol.
- Two field examinations of alternate oil/ethanol chemistries have been undertaken—one at Kalbarri National Park and a second in *Banksia* woodlands of the Northern Swan Coastal Plain. Sorting of material from these trials has been completed and the records have been entered into a database.
- Preliminary analysis of data shows no significant bias in either invertebrate captures or vertebrate by-catch captures between the original glycol based solutions or the new oil/ethanol solutions.

Management implications

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

Future directions (next 12 to 18 months)

- Continue with research and laboratory trials through a collaboration with Curtin University, with the aim of mediating the boundary layer effect that occurs at the interface of oil and ethanol solutions or, alternatively, examine other novel chemical options that may meet the project requirements.
- Establish further field trial sites to test any viable laboratory developments from the collaboration with Curtin University.
- Verify that both vertebrate and invertebrate material is suitable for morphological and molecular studies after immersion in preserving solution.

Northern Goldfields Calcrete Survey: Phase 1

SPP 2011-004

Team members

R Meissner, R Coppen, A Markey, N Gibson

Context

Preliminary results from botanical consultants suggest that calcareous palaeodrainage channels within the northern goldfields support endemic and range-limited taxa, some of which are new to science and of conservation interest. These calcareous palaeodrainage channels are poorly represented on the conservation estate and there is an urgent need to develop a regional dataset to assess future development proposals.

Aims

Undertake a floristic survey of eight to nine calcrete palaeodrainage channels in the northern goldfields and identify biodiversity values (flora and vegetation) of these systems. This land system is poorly reserved and poorly documented, while being highly prospective for mineral exploration and uranium mining.

Summary of progress and main findings

Draft paper, *Flora and vegetation of calcrete palaeodrainage channels in the north-eastern Goldfields*, has been completed and is ready for submission to *Conservation Science Western Australia*.

Management implications

- A regional context will provide improved assessment of the impacts of proposed developments on conservation values of flora and vegetation of calcrete palaeodrainage channel.
- Databases will provide information for use by industry and NGOs in such assessments.

Future directions (next 12 to 18 months)

This project has been completed.

Western Australian wetland fauna surveys

SPP 2011-018

Team members

A Pinder, K Quinlan, RJ Shiels (University of Adelaide)

Context

Regional biological surveys provide analyses of biodiversity patterning for conservation planning at broader scales, but sites in these projects are usually too sparse for use at a more local scale such as individual reserves, catchments or wetland complexes. This project is designed to fill gaps within and between the regional surveys by providing aquatic invertebrate biodiversity data and analyses at higher resolution at such smaller scales. Past examples of such projects are surveys of wetlands in the

Drummond, Warden and Bryde Natural Diversity Recovery Catchments, the Hutt River/Hutt Lagoon catchments and the mound springs near Three Springs. This project will run on an 'as-needed' basis.

Aims

- Provide understanding of medium-scale (catchment/wetland system) aquatic biodiversity patterning to inform local conservation planning and as baselines for future monitoring
- Provide better data on the distribution, ecological tolerances and conservation status of aquatic fauna species and communities.

Summary of progress and main findings

- Sampled and identified aquatic invertebrates at 25 wetlands along the Cervantes to Coolimba coastline.
- Sampled invertebrates at additional occurrences of the Mound Springs of the Three Springs Area Threatened Ecological Community.

Management implications

Wetlands of the Cervantes to Coolimba region support a diverse array of aquatic invertebrates, but most of these are widespread within the south-west of the State. The seasonally inundated salt lakes support most of the known populations of the endemic brine shrimp *Parartemia extracta*.

Future directions (next 12 to 18 months)

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

Western Australian flora surveys

SPP 2012-005

Team members

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

Context

Flora surveys of targeted areas provide knowledge of vegetation pattern and structure for conservation management. Current focus is on the NatureBank survey in Cape Le Grand National Park, and federal Department of Sustainability, Environment, Water, Populations and Communities (DSEWPaC) funded Bush Blitz surveys at Cane River Conservation Park and the former pastoral lease of Credo Station.

Aims

- Undertake floristic survey of Cane River Conservation Park and proposed Credo Station as part of the federally funded Bush Blitz program.
- Undertake preliminary floristic survey of locations in Cape Le Grand National Park as part of the NatureBank program.

Summary of progress and main findings

- Cane River and Credo surveys completed, reports written and voucher specimen lodged.
- Cape Le Grand survey completed, report written and voucher specimens lodged.

Management implications

- Data from Cane River and Credo will increase the ability of regional conservation managers to understand local biodiversity patterning and its underlying drivers. Regional conservation managers can use the data to assess environmental impacts, prioritise conservation actions, set biodiversity management targets and establish baselines for monitoring.

- The Cape Le Grand NatureBank survey identified a new population of a critically endangered plant species which substantially increased the number of plants known in the wild. Data from this survey will inform future management of this area.

Future directions (next 12 to 18 months)

Further short term surveys will be undertaken as required.

FAUNA CONSERVATION PROGRAM

PROGRAM LEADER: KEITH MORRIS

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

Conservation of Western Australian butterflies

SPP 1993-022

Team members

M Williams, A Williams

Context

Invertebrates are a major part of the state's biodiversity and constitute approximately 50% of the state's threatened fauna. This project focuses on a high-profile group of terrestrial invertebrates (butterflies and day-flying moths) that are not sampled using traditional biological survey techniques. By involving community organisations, it extends co-operative partnerships with the community.

Aims

- Undertake research to enhance our ecological knowledge of threatened butterfly and day-flying moth taxa, and identify management strategies to enable effective conservation.
- Implement suitable survey techniques to accurately assess butterfly biodiversity and use these to assess the abundance and species richness of butterflies in remnant bushland areas.
- Determine what factors may be causing loss of butterfly diversity.
- Review the taxonomic status of those taxa where systematics are uncertain, using genetic methods to better delimit those taxa.

Summary of progress and main findings

- Nominated the arid bronze azure butterfly for conservation listing to the Department of Sustainability, Environment, Water, Populations and Communities.
- Internal report on rare Pilbara sun-moths submitted.
- Papers, reports and Information Sheets written and published.

Management implications

Listing of the arid bronze azure butterfly as threatened fauna (Critically Endangered) in Western Australia, and shortly Critically Endangered under Federal legislation will enable effective conservation actions for the species.

Future directions (next 12 to 18 months)

This project has been finalised and need for further work is being reviewed.

Implementation of the recovery plan for the chuditch (*Dasyurus geoffroii*)

SPP 1993-053

Team members

K Morris, B Johnson

Context

The chuditch is currently listed as a threatened species under both the *Wildlife Conservation Act 1950*, and the federal *Environment Protection and Biodiversity Conservation Act 1999* (Vulnerable). A recovery plan was prepared for the species in 1994 and many of the recovery actions have been completed. The recovery plan was revised in 2010 and has been sent to the Department of Sustainability, Environment, Water, Populations and Communities (DSEWPaC) for approval. Translocations have been undertaken to six sites and monitoring of chuditch at other sites has been undertaken as part of the Western Shield fauna recovery program. Translocations are considered to have been successful at three of the six sites, and chuditch abundance appears to have increased at 76% of the Western Shield monitoring sites. Anecdotal sightings also suggest that this species may now no longer meet the International Union for Conservation of Nature (IUCN) criteria for Vulnerable, and should be down-listed. However, a more detailed analysis of the distribution, abundance and population trend is required before this assessment is made.

Aims

- Increase population numbers through the establishment of at least one population outside the present distribution.
- Review the conservation status of the chuditch and revise the recovery plan if necessary.

Summary of progress and main findings

- Ongoing monitoring at key recovery/translocation sites of Lake Magenta Nature Reserve and Julimar Conservation Park was undertaken. No chuditch or any medium-sized mammal species were trapped at Lake Magenta, while abundance at Julimar is within expected limits.
- Revised chuditch recovery plan was approved by DSEWPaC.
- Ongoing monitoring of the trial translocation from Julimar Conservation Park to Francois Peron National Park showed 60% survivorship of founders.
- Trials to examine the impact of feral cat baiting on chuditch at Fitzgerald River National Park and Dryandra suggested that chuditch did not find and/or consume sufficient toxic baits to cause mortality. However, these trials were also shown to be ineffective at controlling feral cats.

Management implications

Review of conservation status against IUCN criteria recommended that the chuditch remain listed as Vulnerable, and the recovery plan was revised accordingly.

Future directions (next 12 to 18 months)

This project has been completed. Requirement for further research is being reviewed.

Factors affecting establishment in the numbat (*Myrmecobius fasciatus*) recovery plan

SPP 1993-145

Team members

T Friend

Context

The numbat is Western Australia‘s state mammal emblem and in 2008 was elevated from Vulnerable to Endangered on the International Union for Conservation of Nature (IUCN) Red List. After a vigorous reintroduction campaign, there are now eight self-sustaining populations but probably less than 1,000

animals in existence. Continued recovery relies partly on private conservation organisations and this project is now orientated towards monitoring populations on DEC-managed estate.

Aims

- Measure the success of establishment of numbat populations through reintroduction and introduced predator control and attribute mortality to specific causes.
- Assess population abundance and trends. If population growth is zero or negative, remove one of the factors causing mortality, and assess the effect of removing the cause of mortality on the growth of the population.

Summary of progress and main findings

- The most recent translocation, to Cocanarup, was monitored through radio-collared animals.
- The annual numbat abundance survey was carried out at Dryandra and results showed that in 2011, as in 2009 and 2010, numbat numbers are lower than at any time since fox control commenced in 1983.
- At Dryandra, analysis of DNA from radio-collars of predated individuals has indicated that cats are the most important predators of numbats.
- Monitoring of established female numbats and their young at Cocanarup has shown good survival and breeding in adult females but high mortality of young. The hypothesis has been formulated that the presence of *Varanus rosenbergii* has more serious implications for numbats than that of *V. gouldii*, more commonly encountered in numbat habitat. Native predators (raptors, pythons, goannas and chuditch) appear to be having a greater impact on the success of the Cocanarup translocation than foxes or cats.

Management implications

- Management of numbat habitat requires ongoing fox control and application of appropriate fire regimes, including protection from large and intense wildfires.
- Rapid implementation of control of feral cats at Dryandra is a high priority if extinction of this critically important numbat population is to be averted.

Future directions (next 12 to 18 months)

This project has been completed. Numbat recovery research and monitoring is being reviewed.

An assessment of the effect of fox control on red-tailed phascogale (*Phascogale calura*) populations

SPP 1993-149

Team members

T Friend

Context

The red-tailed phascogale is ranked Endangered on state, federal and IUCN threatened species lists, although a recent International Union for Conservation of Nature (IUCN) review recommended a down-listing to Vulnerable. This species, present in many small reserves and on private property in the Upper Great Southern and sporadically on the south coast and in the eastern wheatbelt, is a threatened species for which landholders can provide habitat.

Aims

- Assess the effect of fox control on populations of the red-tailed phascogale.
- Determine distribution and habitat preferences of the red-tailed phascogale in the South Coast Region.

Summary of progress and main findings

- Trapping was carried out at all nine fox control research study sites and preliminary analysis of the trapping data indicates that rainfall is the main influence on phascogale numbers.
- Hair funnel surveys were carried out in likely red-tailed phascogale locations in the Fitzgerald River National Park but no positive records were returned.

Management implications

At this stage there is little evidence that fox control is an important requirement for the persistence of remnant red-tailed phascogale populations, although recovery after dry seasons is more rapid under fox control. It is likely that movement between habitat patches and along corridors between reserves is inhibited by fox presence.

Future directions (next 12 to 18 months)

This project has been completed.

Ecology and conservation of threatened pythons in Western Australia

SPP 1993-159

Team members

D Pearson

Context

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

Aims

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

Summary of progress and main findings

- Curation of collected specimens (road-kills) undertaken. Some specimens lodged at the Western Australian Museum.
- Mark-recapture study of carpet pythons on Garden Island has continued with occasional visits during warmer months to measure and mark pythons captured by rangers. A total of 40 new and 10 marked individuals were processed during the year, including snakes marked in 1996.
- Commencement of new study on the population genetics of Pilbara olive python with Dr Peter Spencer of Murdoch University.

Management implications

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

Future directions (next 12 to 18 months)

This project is being reviewed and the requirement for further research evaluated.

Genetics and ecology of the western barred bandicoot (*Perameles bougainville*)

SPP 1993-163

Team members

T Friend

Context

Bernier Island and Dorre Island are of extremely high conservation value because they have retained populations of several mammals that are extinct on the mainland. Recovery of those species relies on reintroductions but for successful outcomes it is vitally important to understand and manage genetic, ecological and disease characteristics that are a result of the long isolation of island populations.

Aims

- Achieve an understanding of the habitat requirements, habitat use, breeding biology and spatial organisation of the western barred bandicoot.
- Assess genetic difference between populations of western barred bandicoots on Bernier Island and Dorre Islands.
- Assess the viability and fertility of progeny from matings between Dorre Island and Bernier Island individuals.
- Investigate the conservation ramifications of disease issues in western barred bandicoots and support veterinary investigations into pathological conditions.

Summary of progress and main findings

An analysis of the genetic variability of the western barred bandicoot populations on Bernier and Dorre Islands and of reintroduced populations at Dryandra and Heirisson Prong has been published.

Management implications

The results of these studies, particularly relating to disease and genetics, will be of great value in managing diseases in wild populations and in translocations of western barred bandicoots and other mammals surviving on islands.

Future directions (next 12 to 18 months)

This project has been completed.

Dibbler (*Parantechinus apicalis*) recovery plan

SPP 1995-011

Team members

T Friend, T Button

Context

The Dibbler Recovery Plan 2003–2013 identifies actions to improve the conservation status of this small marsupial, ranked Endangered on state, federal and International Union for Conservation of Nature (IUCN) threatened species lists. The dibbler survives only in the Fitzgerald River National Park and on Boullanger and Whitlock Islands off Jurien Bay. Two other populations, on Escape Island off Jurien Bay and at Peniup proposed Nature Reserve, have been established by translocation. Another attempted reintroduction, to the Stirling Range National Park, has been deemed a failure.

This project implements research actions from the Recovery Plan and includes monitoring of all known dibbler populations. It involves collaboration with DEC South Coast and Midwest Regions, South Coast NRM, University of Western Australia, Perth Zoo and local community members.

Aims

- Protect and monitor existing populations.
- Increase the number of known populations by searching for undiscovered populations and re-establishing dibblers in areas where they have become extinct.
- Document and explain dibbler distribution in the Fitzgerald River National Park.

Summary of progress and main findings

- The population study in the eastern Fitzgerald River National Park continued, but only two of the scheduled four annual monitoring sessions were carried out at the study site, in July 2011 and January 2012. Numbers have recovered somewhat following the good rains of winter 2011 and nine individuals were captured in January, albeit well short of the highest January capture recorded so far of 39 in 2008.
- At Peniup, the latest series of releases of dibblers has been successful, with 28 individuals captured in September 2011. The final release proposed for October 2011 was cancelled and the release group of 61 dibblers used instead to commence a full translocation into the Waychinicup enclosure. Subsequent monitoring at Peniup has resulted in the capture of dibblers on the trapping grids, indicating a healthy population coming into the May breeding season.
- The Boullanger and Whitlock island populations were monitored and indicated a recovery from the low numbers of 2011, following the good rains of winter 2011.

Management implications

- Results from both Peniup and Stirling Range National Park indicate strongly that monthly ground baiting is necessary to maintain dibbler populations, at least in small isolated remnants and in large areas adjacent to farmland.
- Dibbler populations respond strongly to winter rainfall, with population crashes following dry winters.
- Large and intense wildfires diminish dibbler habitat for at least five years under fox control and 15 years without fox control.

Future directions (next 12 to 18 months)

This project is being reviewed.

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

SPP 1996-008

Team members

T Friend, S Hill, T Button

Context

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

Aims

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

Summary of progress and main findings

- A census of the Mount Gardner population of Gilbert's potoroos is conducted three times a year. Numbers have remained stable since 2001 when this regime was introduced. Numbers captured were 15 in June/July 2011, 20 in November 2011 and 15 in March 2012.
- The translocated population on Bald Island has grown rapidly from the founder number of ten. Sixty-six independent potoroos, including five of the ten founders from 2005–2007, were captured in the most recent full census in June 2012, despite the removal of a total of 33 potoroos between 2008 and 2011.
- A further 12 animals were transferred from Bald Island to the Waychinicup National Park enclosure. Monitoring of the Waychinicup enclosure population by trapping, radio-tracking and motion-activated cameras has shown that the potoroos use vegetation types other than that occupied at Two Peoples Bay and that breeding and recruitment are occurring (five independent young have been recorded so far).

Management implications

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

Future directions (next 12 to 18 months)

- Continue to monitor the Mount Gardner population and the Bald Island translocation.
- Continue the study of fox bait consumption at Two Peoples Bay using motion-activated cameras.
- Monitor establishment of Gilbert's potoroos within the Waychinicup National Park enclosure. Continue to monitor the enclosure for incursion by cats or foxes. Implement structured trapping to determine habitat use.
- Evaluate further translocation sites, both on the mainland and on other islands.
- A paper on the population dynamics of Gilbert's potoroo at Two Peoples Bay will be submitted for publication.

Implementation of the Lancelin Island skink recovery plan

SPP 1999-011

Team members

D Pearson

Context

The only wild population of the Lancelin Island skink is found on Lancelin Island. A translocated population was established on Favorite Island in Jurien Bay in 2002. This project continues the actions identified in the *Lancelin Island Skink Recovery Plan* to improve the conservation status of the species.

Aims

- Implement the *Lancelin Island Skink Recovery Plan*, especially the establishment and monitoring of a translocated population on Favorite Island.
- Update the actions of the recovery plan in conjunction with the Lancelin Island Skink recovery team to incorporate research findings and plan future research or management actions.

Summary of progress and main findings

Monitoring of Lancelin Island and Favorite Island populations has been planned.

Management implications

- Monitoring has shown that the translocation of Lancelin Island skinks to Favorite Island has been successful. This action in the recovery plan has reduced its vulnerability to a natural or anthropogenic disturbance that might threaten the Lancelin Island population.
- The project has identified how the skinks can be bred and translocated if this action is required in the future.

Future directions (next 12 to 18 months)

Production of paper on the translocation of captive bred skinks to Favorite Island.

Probait trials: Phase 2

SPP 2000-014

Team members

N Marlow, A Williams

Context

Fox control at Dryandra Woodland has been found to be less effective than predicted. A possible reason for this may be a loss of 1080 from baits. Trials are needed to assess whether the 1080 content of baits decreases to non-lethal levels between baiting sessions or during manufacture, storage or transport.

Aims

Determine whether Probaits contain a lethal dose of 1080 for fox control.

Summary of progress and main findings

- Toxic baits (3mg 1080) were fed to a sample of three wild caught foxes to determine if sufficient 1080 was present within the baits to kill an adult fox.
- All foxes died within six hours of ingesting the toxic 1080 baits, indicating the baits were efficacious.

Management implications

The results of this trial show that, if ingested, 3mg Probaits are effective in killing foxes. This means that continued use of Probaits within DEC's Western Shield fox baiting programme can be continued with confidence.

Future directions (next 12 to 18 months)

This project is completed.

Return to Dryandra

SPP 2003-002

Team members

N Thomas, N Marlow

Context

Developing cost effective captive breeding techniques and an understanding of effective reintroduction methodologies that can be implemented at an operational regional level is a priority of the Western Shield program. In 1998, the Return to Dryandra project was established to investigate the best methodology to captively breed and maintain five locally-extinct wheatbelt mammal species within large enclosures at Dryandra; to investigate a range of reintroduction techniques; and to provide animals for reintroduction to Western Shield fauna reconstruction sites where fox control is in place at a regional scale.

Aims

- Provide a scientific basis for the establishment and maintenance of breeding populations of at least five critical weight range (CWR) threatened marsupial species (bilby, boodie, marl, mala and merrnine) from remote areas in large enclosures at Dryandra.
- Establish self-sustaining populations of these CWR threatened marsupial species within enclosures at Dryandra.
- Compare the success of different release and reintroduction methodologies for these CWR threatened marsupial species within the Dryandra woodland.
- Establish self-sustaining populations of these re-introduced CWR threatened marsupial species within the Dryandra woodland and other Western Shield fauna reconstruction sites.

Summary of progress and main findings

- Approximately six marl are persisting in the facility.
- The last remaining boodie has been relocated to Lorna Glen.
- In Autumn 2012, 13 mala were relocated to Lorna Glen, seven to 10 mala remain at Dryandra.

Management implications

The ongoing future of the breeding facility needs to be considered by the Department, taking into account translocation proposals over the next few years.

Future directions (next 12 to 18 months)

This project has been completed.

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

SPP 2003-005

Team members

D Algar, N Hamilton, M Onus

Context

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

Aims

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

Summary of progress and main findings

- Preliminary work has been conducted for the cat eradication program on Dirk Hartog Island as part of the ‗Dirk Hartog Island National Park Ecological Restoration Project'. This work has focussed on the termination points of the barrier fence at the lagoon and cliff edges. Research has also commenced on optimising the placement of the monitoring grid network.

- Stage 1 of the management plan for the control of cats and black rats on Christmas Island has been completed and Stage 2 implemented. All domestic cats have been de-sexed, micro-chipped and registered, and over three hundred stray/feral cats have been removed. For the first time in five years there has been nestling success of the red-tailed tropicbird, a result of cat removal from the shoreline colony.
- A plan for cat baiting on the Fortescue March has been written and is currently being implemented.
- Research into the effectiveness of baiting strategies is now being assessed under the temperate climatic conditions of the south-west at Cape Arid National Park

Management implications

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

Future directions (next 12 to 18 months)

- Analyse baiting effectiveness at the various research sites and refine the method of operation where necessary.
- Conclude the registration process for the Eradicat® bait with the Australian Pesticides and Veterinary Medicines Association.

Impact of cane toads on biodiversity in the Kimberley

SPP 2006-004

Team members

D Pearson

Context

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

Aims

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

Summary of progress and main findings

- Frog call data were collected at numerous sites around Kununurra and are being analysed to see if any species were measurably affected by the arrival of toads.
- Radio-telemetry of olive pythons (10), king brown snakes (six) and black-headed pythons (four) was undertaken during the cane toad invasion.
- Several field trials were undertaken of a taste aversion 'bait' to train native predators to avoid cane toads.

Management implications

The project has monitored the fate of several species believed to be at significant risk from cane toads during their invasion. Several native predators were identified as being at particularly high risk. Captive trials were undertaken to determine if taste aversion training was possible. Trials with quolls and floodplain goannas suggested that the technique had merit and has been followed up with field trials that are ongoing. If the bait is successful, it provides a means to retain populations of susceptible predators (goannas, large snakes and blue tongue lizards) in pockets across the Kimberley landscape.

Future directions (next 12 to 18 months)

- Testing of the CTA baits to teach naïve Kimberley predators to avoid toads and determine if there are any non-target effects.
- Publication of studies on the susceptibility of Kimberley snake and goanna species to poisoning from cane toads.

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

SPP 2006-005

Team members

P De Tores

Context

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

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

Aims

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

Summary of progress and main findings

- Analysis of fox and cat activity revealed strong evidence for mesopredator release of cats in the presence of long-term fox control.
- At a key monitoring site (George Forest Block) at the forest interface with agricultural land, where fox density was reduced by baiting, reinvasion by foxes was sufficient for competition to prevent cat abundance from increasing. At this site, with reduced fox abundance and no increase in cat abundance, chuditch abundance increased, as did woylie abundance. The results provide strong evidence that predation by introduced predators is the primary cause for woylie decline.
- Book chapter on the relative merits of exclusion fencing and baiting was published.

Management implications

- Fox and cat control will need to be integrated through strategic control programs for both species.
- Broad-scale cat control in the south-west is not possible until a suitable bait is developed.
- The effectiveness of integrated baiting programs will need to be monitored through techniques suitable for the targeted species.

Future directions (next 12 to 18 months)

This project has been completed.

Translocation outcomes and monitoring of naturally occurring populations of the western ringtail possum (*Pseudocheirus occidentalis*)

SPP 2006-006

Team members

P De Tores

Context

The western ringtail possum translocation program commenced in 1991 and by 1998 appeared to have met the criteria for success. The primary translocation release site, Leschenaultia Peninsula Conservation Park, subsequently suffered a population decline. Low density populations have persisted at three translocation release sites within Yalgorup National Park. Possible causes for the decline at Leschenault are being investigated and are: factors influencing survivorship of naturally occurring populations; the health of naturally occurring and translocated populations; the role of predation by pythons in translocation outcomes; the genetics of western ringtail possums; and techniques for determining population density at sites within the Busselton area thought to be at relatively high density.

Aims

Determine translocation success of western ringtail possums at Leschenault Peninsula Conservation Park and Yalgorup National Park.

Summary of progress and main findings

- Although no causal link was identified, survivorship of translocated western ringtail possums was negatively associated with high numbers of the sympatric common brushtail possum (*Trichosurus vulpecula hypoleucus*) and negatively associated with high pre-translocation lymphocyte counts.
- Reference values and baseline information on the haematological and biochemical profiles have now been established for coastal populations.

Management implications

- The findings from the limited genetic research to date has implications for western ringtail possum conservation, as mixing of populations through translocation has the potential to dilute the naturally occurring genetic structure.
- There will be a continued need for translocation of possums and an additional requirement to release orphaned and injured possums that have been nurtured and/or rehabilitated by wildlife carers. In order to meet conservation and community expectations, the current high rate of loss of animals to predation by cats needs to be addressed at translocation sites.

Future directions (next 12 to 18 months)

This project has been completed.

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

SPP 2006-007

Team members

N Marlow, A Williams

Context

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

Aims

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

Summary of progress and main findings

- Monitoring of woylie populations in Dryandra Woodland and Tutanning Nature reserve was undertaken. Comparative survival is being calculated using the live captures component of the Program MARK analysis package.
- The predominate predator of woylies in Dryandra Woodland and Tutanning Nature reserve is the feral cat. Mesopredator release of feral cats in fox baited areas appears to have occurred.
- Western Shield monitoring in Tutanning Nature Reserve in 2011 resulted in no captures of woylies. Subsequent, intensive trapping at Tutanning Nature Reserve resulted in the capture of two individuals (one male and one female).
- Some fox predation of woylies continues to occur due to a very high uptake of baits by non-target species (birds and brushtail possums) and thus baits are not available for fox control. Increasing the intensity of fox baiting to 50 baits per square kilometre did not result in increased woylie survival. It appears there was an increase in cat predation when increased fox control was implemented.
- Although some foxes appear to persist within the two baited areas for more than one baiting event, the fox baits (3mg Probaits) are still effective in killing the majority of foxes that enter these areas, as evidenced by the serendipitous collection of numerous fox carcasses and 90–95% of foxes only being detected on one occasion based on DNA analysis.

Management implications

- The development of an operational cat control methodology that is effective in killing cats throughout the year and in sites where non-target species are present is of paramount importance.
- When available, the cat control methodology needs to be combined with increased intensity fox baiting to improve the efficacy of predator control and to afford the recovery of faunal populations.

Future directions (next 12 to 18 months)

- Complete data analysis from fox and cat monitoring in Dryandra Woodland and Tutanning Nature reserve and identify whether a mesopredator release of feral cats in the presence of fox control can be quantified.
- Incorporate the latest Western Shield monitoring data into the analyses resulting from the mesopredator project, complete all relevant manuscripts.

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

SPP 2006-009

Team members

K Morris

Context

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

Aims

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

Summary of progress and main findings

- Completed IA CRC reports and continued with data analysis and preparation of DEC report.

Management implications

This project has demonstrated that a simultaneous ground and aerial baiting regime is more effective at controlling foxes than one where ground and aerial baits are laid at different times. It has also demonstrated the value of sand plots as an operational tool to assess fox and cat activity and relative abundance. It was intended to be able to deploy a cat bait at Lake Magenta to further improve fauna conservation; however non-target uptake issues have not been resolved and an operational cat bait is not yet available for use in the south-west of Western Australia. It would be extremely desirable for the District to continue monitoring the native fauna, and fox and cat activity at Lake Magenta, at least annually.

Future directions (next 12 to 18 months)

- Publish results and prepare final report.
- Facilitate the annual monitoring of Lake Magenta by the District.
- Incorporate the simultaneous ground and aerial fox baiting at Lake Magenta into Western Shield baiting protocols.

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

SPP 2007-002

Team members

A Wayne, C Ward, C Vellios, M Maxwell

Context

The woylie *(Bettongia penicillata*) has declined by about 90% since 2001. Population declines have been rapid (<95% per annum), substantial (>90% lost) and have particularly impacted the largest and most important populations. The declines are continuing in some areas and as yet there has been no sustained post-decline recovery. Most of the remaining unaffected populations are small (<300 individuals), isolated and inherently vulnerable. The woylie has been relisted as Endangered at the state and federal level and Critically Endangered by the International Union for Conservation of Nature (IUCN).

Aims

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

Summary of progress and main findings

- Ongoing monitoring indicates numbers have remained relatively stable at a regional level since 2008 but declines continue at key sites such as Keninup and Warrup.
- Evidence indicates that the woylie declines have been mortality driven, principally due to the predation (particularly by cats) of individuals thought to have become increasingly vulnerable due to disease.
- Woylies in the Perup Sanctuary have tripled from their founder size of 41 in the first 18 months since December 2010.
- Collaborative disease investigations continue, particularly into the key associations with the declines.

Management implications

- The risk of local extinction of some indigenous and important populations remains high, including Batalling and Tutanning. Effective predator control for feral cats and foxes is critical for sustaining important woylie populations.
- Wildlife disease monitoring and management are important for conservation of this species and other wildlife.
- The outcomes of this work are directly relevant to determining the causes of declines in other species that may be more difficult to study directly.

Future directions (next 12 to 18 months)

- Continued publication of results to date.
- Determine the success of the insurance populations through ongoing monitoring and continue the identification of causes of the declines/limitations to recovery.

Sustained introduced predator control in the rangelands

SPP 2007-004

Team members

D Algar

Context

The project will provide for the successful reconstruction and conservation of biodiversity as part of the future expansion of the Western Shield program into this region. The program builds on the successful research programs and operational trials conducted in the interior of the arid zone at the Gibson Desert Nature Reserve and more recently at Lorna Glen. The research is focussed on Australian Wildlife Conservancy's Mt Gibson Sanctuary and at the nearby DEC-acquired pastoral leases of Karara–

Lochada. Feral cat bait and baiting methodologies (i.e. timing of baiting, baiting intensity and frequency) will be employed to assess an integrated introduced predator (feral cat, fox and wild dog) control strategy.

Aims

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

Summary of progress and main findings

Final report to the Invasive Animals Cooperative Research Centre completed.

Management implications

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

Future directions (next 12 to 18 months)

Write papers to publish project results.

Conservation of the graceful sun-moth

SPP 2010-006

Team members

C Bishop, A Williams, J Fissioli, M Williams

Context

This project focuses on a high-profile threatened invertebrate that is listed as an Endangered species under the federal *Environment Protection Biodiversity Conservation Act 1999*, and as declared rare 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 that 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 co-operative 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 what factors determine the realised niche of the species using habitat suitability modelling.
- Review the conservation and taxonomic status of the graceful sun-moth using molecular genetic methods.
- Identify management strategies to enable effective conservation.

Summary of progress and main findings

- Presented talks to the Western Australian Insect Study Society and to the Urban Bushland Council.
- Conservation status of graceful sun-moth has changed from Endangered to Vulnerable.

Management implications

Information on the distribution, abundance and habitat requirements of the graceful sun-moth has enabled conservation status to be downgraded from Endangered to Vulnerable.

Future directions (next 12 to 18 months)

- Further examination of genetic variability within populations of graceful sun-moth will be undertaken.
- Further examination of hybrid populations between the coastal graceful sun-moth (*Synemon gratiosa*) and inland claret sun-moth (*Synemon jcaria*).

Ecology and management of the northern quoll in the Pilbara

SPP 2011-005

Team members

A Cook, K Morris

Context

The northern quoll *Dasyurus hallucatus* is listed as an Endangered species under the federal *Environment Protection Biodiversity Conservation Act 1999*. Mining offset provisions are being used to gain a better understanding of quoll distribution, ecology 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 timeframe will provide information relevant to impacts, such as loss of known or potential habitat critical to the survival of the species, loss of known or potential foraging/dispersal habitat, and introduction of barriers restricting dispersal opportunities and genetic flow.

Aims

- Improve understanding of northern quoll population distribution, ecology and demographics in the Pilbara.
- Provide information to resource development companies that will allow appropriate management of mining sites to ensure the persistence of resident northern quoll populations.

Summary of progress and main findings

- Monitoring of sites identified by BHP Billiton has commenced.
- Consultation with landholders to gather anecdotal and historical records of northern quoll distribution has commenced.
- Distributional study using motion sensor cameras has commenced.

Management implications

Improved understanding of northern quoll ecology and distribution in the Pilbara will allow appropriate management of northern quoll populations in and around mining sites and other developments.

Future directions (next 12 to 18 months)

- Field trips will be undertaken to deploy motion sensor cameras at up to 100 sites to record presence/absence data and patterns of distribution across the Pilbara region, assist in identifying key quoll habitat characteristics and to facilitate the identification of appropriate long-term monitoring sites.
- Consultation with landholders to gather anecdotal and historical records of northern quoll distribution will continue.
- Long-term regional monitoring will commence in early 2013 and monitoring of disturbed areas will be conducted twice annually.

Conservation of south coast threatened birds

SPP 2012-022

Team members

A Burbidge, South Coast Region staff

Context

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

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 parrots, western bristlebird and western whipbird and increase their total population size through creation of management prescriptions that will benefit all threatened south coast animals.

Summary of progress and main findings

- Continued integrated predator management on the south coast in an adaptive management framework.
- Commenced a study to improve ways of evaluating success of scrub-bird translocations.
- In collaboration with DEC South Coast Region, continued to develop a captive management program for western ground parrots.

Management implications

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

Future directions (next 12 to 18 months)

- Finalise writing up of data on response to fire by bristlebirds.
- Write up data on the status of the western ground parrots.
- Implement further field-scale feral cat control (with monitoring) in key ground parrot habitat.
- Using previously gathered data on genetic relatedness of captive ground parrots, develop protocols for establishment of a captive breeding program for western ground parrots.

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

SPP 2012-033

Team members

K Ottewell, M Byrne, K Morris, D Coates, A Burbidge, L Gibson, R How (Western Australian Museum), P Doughty (Western Australian Museum), B Chambers (University of Western Australia), L Valentine (Murdoch University), A Hillman (Murdoch University)

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

Summary of progress and main findings

- Sourced quenda tissue samples and associated data from monitoring programs within DEC.
- Initiated collaborations with researchers at the University of Western Australia and Murdoch University to extend sampling range beyond DEC's collections.
- Trialled DNA extraction protocols on quenda tissue samples and trialled eight published *Isoodon obesulus* ssp. *obesulus* microsatellite markers to test for polymorphism in quenda (*I. obesulus* ssp. *fusciventer*).

Management implications

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

Future directions (next 12 to 18 months)

- Complete DNA extractions, develop additional quenda-specific microsatellite markers and genotype quenda population samples from the coastal plain and Perth Hills.
- Analyse genetic diversity and genetic differentiation between populations and correlate this information with habitat data collected by Swan District.
- Finalise target species for Pilbara genetics project and initiate sample collection from DEC and Museum tissue collections.
- Develop mitochondrial and nuclear DNA sequence markers variable in Pilbara target species and complete sequence analysis.

Genetic assessment for conservation of rare and threatened fauna

SPP 2012-034

Team members

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

Context

Genetic analysis of threatened species can provide important information to support and guide conservation management. In particular, genetic tools can be used to aid resolution of the taxonomic identity of species to determine whether they have appropriate conservation listing. At a population level, analysis of the genetic diversity present in extant populations informs us of the genetic 'health' of

threatened species and how this may be maintained or improved through management actions leading to long-term positive conservation outcomes.

Aims

- Resolve taxonomic boundaries of Western Australian bandicoots (*Isoodon* sp.), particularly *I. auratus* and *I. obesulus* and their sub-species, to determine appropriate conservation rankings.
- Assess genetic diversity and effective population size of source and translocated populations of golden bandicoot (*Isoodon auratus*) and perform population viability analysis to predict long-term trajectory of translocated populations.

Summary of progress and main findings

- Sourced *Isoodon auratus* and *I. obesulus* samples from monitoring programs within DEC.
- Trialed DNA extraction protocols on golden bandicoot tissue samples.
- Trialed eight published *Isoodon obesulus* ssp. *obesulus* microsatellite markers to test for polymorphism in *I. auratus.*

Management implications

- Resolution of taxonomic boundaries between *I. obesulus* and *I. auratus* will enable revision of current threatened species status.
- Information on the genetic diversity and effective population size of translocated populations of golden bandicoot will provide an assessment of the success of current management actions and whether further action is required (e.g. genetic augmentation).

Future directions (next 12 to 18 months)

- Finalise collection of *I. auratus* and *I. obesulus* tissue samples and complete DNA extractions.
- Develop additional golden bandicoot-specific microsatellite markers and genotype source and translocated populations. Analyse genetic diversity and genetic differentiation between populations and perform population viablility analysis using demographic and genetic data.
- Develop mitochondrial and nuclear DNA sequence markers that provide appropriate resolution between *Isoodon* taxa to resolve taxonomic boundaries.

FLORA CONSERVATION AND HERBARIUM PROGRAM

PROGRAM LEADER: DAVID COATES

Applied flora conservation research seeks to understand the factors and processes that are critical for the conservation of Western Australia's native plant diversity. Major objectives include ensuring the persistence of rare and threatened species, ameliorating key threats such as *Phytophthora* dieback and weeds, and improving understanding of genetic and ecological factors that are vital for the long-term viability of plant species. This research is aligned to the information needs of the Department of Environment and Conservation (DEC). 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, which underpins their conservation. 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.

Taxonomic review and conservation status of the members of the Myrtaceae tribe Chamelaucieae and miscellaneous other Western Australian plant groups

SPP 1993-011

Team members

B Rye

Context

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

Aims

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

Summary of progress and main findings

- A paper on *Petrophile* (Proteaceae) was published and a poster was presented at the XVIII International Botanical Congress.

- A paper introducing the interactive key to the Myrtaceae tribe Chamelaucieae has been submitted and a poster on this topic was presented at the XVIII International Botanical Congress. Since then, *Chamelaucium* and *Darwinia* have been added to complete the key's coverage of the tribe.
- Several papers in an advanced stage of preparation, including one on *Babingtonia* that has been submitted for internal approval.

Management implications

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

Future directions (next 12 to 18 months)

- Official release of the interactive key through publication of an introductory paper in *Nuytsia*. Hold a workshop to demonstrate the key.
- Submit papers on *Astartea, Babingtonia* and *Cyathostemon* (Myrtaceae).
- This project is being reviewed.

Integrated strategies for the control of *Phytophthora cinnamomi* using phosphite

SPP 1993-068

Team members

B Shearer, C Crane

Context

Understanding long-term effects of control of *Phytophthora cinnamomi* by phosphite application is important for developing and implementing ecologically appropriate control options for the management of *P. cinnamomi*. This study was designed as a series of long-term experiments.

Aims

Understand the effectiveness of phosphite against *P. cinnamomi* in native flora for long-term control of the pathogen.

Summary of progress and main findings

During the project 12 student projects were supported and 93 reports, publications and presentations were made.

Management implications

Effective methods of *P. cinnamomi* control using phosphite will provide options for the management of dieback infections.

Future directions (next 12 to 18 months)

The project is completed and will be closed.

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

SPP 1998-003

Team members

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

Context

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

Aims

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

Summary of progress and main findings

- A set of variable chloroplast sequences for molecular taxonomy at low Hierarchical levels have been developed and a journal paper detailing their application has been submitted to *American Journal of Botany*.
- Molecular and morphological investigation of taxonomic relationships among populations of *Pityrodia scabra* have revealed two subspecies that differ in the arrangement of the leaves and the shape of the bracts. *Pityrodia scabra* subsp. *dendrotricha* KASheph. *sp. nov*. is listed as a taxon of conservation concern as it is currently only known from three disjunct populations in the southern wheatbelt and goldfields regions of Western Australia, while *P. scabra* subsp. *scabra* remains Critically Endangered. A journal paper has been submitted to *Australian Systematic Botany*.
- A paper detailing the most variable gene regions for phylogeographic analysis has been submitted to *Australian Journal of Botany*.
- Investigation of genetic diversity in *Atriplex* sp. Yeelirrie Station showed very high differentiation between the two population groups located approximately 30km apart in a paleodrainage channel in central Western Australia. A paper has been published in *Australian Journal of Botany*.
- Analysis of phylogeographic structure in *C. quadrifidus* has revealed the present of historical refugia in the Kalbarri/Shark Bay region, along the south coast and on the inland granite outcrops and greenstone ranges. Haplotype distribution reflecting evolutionary patterns supports the recent taxonomic revision of the species. A paper has been submitted to *Journal of Biogeography*.
- Analysis of genetic diversity in *C. quadrifidus* using AFLP markers is being undertaken to determine the patterns of genetic structure in the complex.
- Analysis of genetic structure in *Pultenaea pauciflora* suggests the presence of two cryptic sister taxa, with significant differentiation between populations at Narrogin and Brookton and those at Boddington, indicating the need for reassessment of the taxonomic and conservation status of both lineages. Cytogenetic analysis confirmed populations from all locations were diploid. A paper describing the genetic structure has been submitted to *Biological Journal of the Linnaean Society*.

- Analysis of chloroplast haplotype diversity has been undertaken in *Lepidosperma* sp. Parker Range and *Lepidosperma* sp. Mt Caudan. Microsatellite markers have been developed for nuclear genetic analysis in *Lepidosperma* sp. Parker Range and *Lepidosperma* sp. Mt Caudan.

Management implications

- Assessment of the genetic structure within collections of *Synaphea* from the Pinjarra Plains will inform taxonomic revision and determine the identity of questionable populations of Declared Rare Flora taxa.
- Assessment of genetic differentiation in *Eremophila microtheca* and *E. rostrata* will assist in determination of sub-specific taxa, and clarification of Declared Rare Flora status.
- Assessment of genetic differentiation in *C. quadrifidus* has supported taxonomic revision of the group.
- Taxonomic revision and revised assessment of conservation status of *Banksia mimica* taxa is required.
- Clarification of the genetic relationships among populations of *Pultenaea pauciflora* has revealed the need for a morphological assessment and taxonomic reassessment of the species.
- Resolution of the taxonomic status of *Pityrodia scabra* ssp. *dendrotricha (*previously *Pityrodia* sp. Yilgarn) has enabled conservation assessment as Priority Three as it is known from several populations that are not under immediate threat.
- Clarification of taxonomic status of *Platytheca* sp. Sabina, *Hakea* aff. *prostrata*, *Pityrodia* sp. Yilgarn, and *Hydrocotyle scutellifera* and associated taxa will enable evaluation of conservation status and implementation of conservation actions if required.
- Assessment of genetic diversity and genetic structure will provide information to ensure the long-term maintenance of genetic diversity in *Lepidosperma* sp. Parker Range and *Lepidosperma* sp. Mt Caudan during mining operations in the Parker Range.

Future directions (next 12 to 18 months)

- Analysis of *Eremophila microtheca* and *E. rostrata* will be completed to determine possible subspecies status within each species.
- Analysis of genetic structure within *C. quadrifidus* and allied taxa will be completed.
- Taxonomic revisions of *Platytheca* sp. Sabina, *Hakea* aff. *prostrata*, *H. scutellifera* and associated taxa will be completed.
- Analysis of genetic diversity and genetic structure will be undertaken for *Lepidosperma* sp. Parker Range and *Lepidosperma* sp. Mt Caudan.

Australian wattle identification

SPP 1999-005

Team members

B Maslin, J Rogers, C Parker, K Thiele

Context

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

Aims

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

Summary of progress and main findings

- All new and modified Flora of Australia treatments has been provided to ABRS through facilities provided by ALA.
- Work on updating and verifying encoded data in the WATTLE database was completed.
- Interactions with institutions and individuals were undertaken to acquire photographs for delivery via WATTLE.
- All relevant images of Australian taxa of *Acacia* have been posted on the WorldWideWattle website.
- New character states for WATTLE key (text and illustrations) have been completed.

Management implications

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

Future directions (next 12 to 18 months)

For each taxon provide current descriptive and associated information and (where available) photographs.

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

SPP 1999-010

Team members

A Cochrane, A Crawford, A Monaghan, S Dudley, R Elkins, D Coates

Context

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

Aims

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

Summary of progress and main findings

- 138 seed collections lodged at the Threatened Flora Seed Centre (106 Declared Rare Flora [DRF], nine Priority, and 23 common) including collections from 51 rare and threatened flora collected, processed and incorporated into the seed bank.
- Total number of collections stored in the Threatened Flora Seed Centre is now 3,630 (1,732 DRF, 973 Priority, and 925 common).
- 78% of DRF and 22% of Priority taxa are now in storage in the Threatened Flora Seed Centre.

- 323 collections cleaned and stored (205 DRF, 42 Priority and 76 common collections).
- 158 germination tests conducted (115 DRF, 20 Priority and 23 common collections).
- Material of 149 collections duplicated for safekeeping with the Millennium Seed Bank Project in the UK .
- Provision of germinated seeds for translocation of 14 critically endangered species.
- Combined DEC/BGPA final report provided to Millennium Seed Bank Project for the period 2001–2011.
- Paper on the one-step fitting of seed viability constants for two Australian species submitted to *Australian Journal of Botany*.

Management implications

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

Future directions (next 12 to 18 months)

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

Susceptibility of rare and endangered flora to *Phytophthora*

SPP 1999-019

Team members

B Shearer, C Crane

Context

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

Aims

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

Summary of progress and main findings

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

Management implications

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

Future directions (next 12 to 18 months)

- Update database and analyse trends within database.

- Determine variation in susceptibility of four *Banksia* species across a climate gradient on the south coast.

The population ecology of critically endangered flora

SPP 2000-015

Team members

C Yates

Context

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

Aims

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

Summary of progress and main findings

- Continued monitoring the recovery of the Critically Endangered Eastern Stirling Range Montane Heath and Thicket community from fire.
- Commenced analysis of the impacts of fire and *Phytophtora cinnamomi* on the composition and dynamics of the Montane Heath and Thicket community.
- Prepared a summary of the initial findings of the Montane Heath and Thicket community study for inclusion in a book chapter on long-term trends in Australian heathlands to be published in a book on long term ecological research.
- Continued monitoring the demography of the Critically Endangered *Verticordia staminosa* subsp. *staminosa* in relation to climate change.
- Published a manuscript in *Australian Journal of Botany* on the ecological relationships and demography of threatened *Tetratheca* taxa endemic to Banded Iron Formation ranges.

Management implications

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

Future directions (next 12 to 18 months)

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

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

SPP 2001-001

Team members

D Coates, M Byrne, S McArthur

Context

Understanding the interaction between mating systems, levels of inbreeding and patterns of genetic variation within populations of species is a key element in assessing the viability of plant populations, particularly rare and threatened taxa, and the development of management strategies that reduce the likelihood of local extinction.

Aims

- Assess the relationship between effective population size and levels of genetic diversity, and the minimum effective population size for maintaining genetic diversity.
- Assess the effects of population size and habitat degradation on mating system parameters that indicates 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 between rare and common congeners, which provide a more general understanding of rarity in this flora and how it can be managed.

Summary of progress and main findings

- A paper is in preparation on significant genetic structure in *Banksia brownii* associated with three geographically distinct population groups, and the loss of substantial genetic diversity through the extinction of populations across the species range.
- A paper on temporal and spatial patterns of mating system variation in *Banksia cuneata* has been drafted and will be submitted to *Australian Journal of Botany*.
- Date analysis on mating system variation in two sister triggerplant species (*Stylidium affine* and *Stylidium maritimum*) with contrasting breeding systems is currently underway.

Management implications

- Assessment of genetic variation will inform prescriptions for the prevention of inbreeding and maintenance of genetic variation in small fragmented populations of rare and threatened plants, and will facilitate strategies for managing inbreeding and loss of genetic diversity during translocation programs.
- The mating system studies on *Banksia cuneata* indicate increased fluctuations in outcrossing rate over years following habitat disturbance and suggest that temporal stability in the mating system may be a significant factor when considering effects of habitat disturbance on plant populations. Spatiotemporal mating system variation warrants increased consideration in the design and establishment of success criteria in ecological restoration and translocation programs.
- Translocation programs for *Banksia brownii* should continue to mix seed collections from within the three eco-geographic regions but translocations should not yet be established with seed mixes from different regions.

Future directions (next 12 to 18 months)

- Submit paper on temporal and spatial patterns of mating system variation in *Banksia cuneata* to the *Australian Journal of Botany*.
- Submit paper on genetic structure and the impact of localised extinction on genetic diversity levels in *Banksia brownii*.

- Complete analysis of the mating system in two *Stylidium* species, and prepare a paper for publication.

Translocation of critically endangered plants

SPP 2001-004

Team members

L Monks, R Dillon, D Coates

Context

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

Aims

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

Summary of progress and main findings

- Infill planting was completed for translocations of nine Critically Endangered plant species.
- Monitoring was undertaken for 30 translocations planted in previous years.
- Ongoing development of flora translocation database and collation of flora translocation data from across DEC.
- Two book chapters were published on translocation success in long-lived plants and on the Centre for Plant Conservation (USA) guidelines for plant reintroductions.
- Assisted DEC District and Regional staff plan and implement a range of flora translocations.

Management implications

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

Future directions (next 12 to 18 months)

- Continue the planting of experimental translocations of Critically Endangered plant species and other priority threatened flora where further translocations are deemed necessary.
- Continued monitoring of DEC threatened flora translocations and further development of criteria for evaluating success such as PVA, mating system and genetic variability analysis.
- Analyse and publish translocation methodology data, translocation summary data, *Lambertia orbifolia* PVA modelling data and *Acacia* translocation success study.

Genetic and ecological viability of plant populations in remnant vegetation

SPP 2002-001

Team members

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

Context

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

Aims

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

Summary of progress and main findings

- A paper assessing the influence of different aspects of habitat fragmentation on mating patterns and pollen dispersal in *Banksia sphaerocarpa* has been published in *Molecular Ecology*. A paper on the influence of habitat fragmentation and mating system variables on reproduction and progeny fitness in *B. sphaerocarpa* has been completed and another paper detailing the genetic structure in the *B. sphaerocarpa* study area is in preparation.
- In *B. sphaerocarpa*, most mating system and pollen dispersal measures showed ‗healthier' levels in the large study population compared with eight small, highly fragmented study populations. The results suggest that the effect of linear population shape on mating system and pollen dispersal is often underestimated. Changes in the mating system caused by population fragmentation are significantly correlated with reduced seed weight, seed germination and seedling growth. The reduction in progeny fitness will reduce the viability of many population fragments.
- Paper on impacts of fragmentation on pollen dispersal and genetic diversity in *Calothamnus quadrifidus* ssp. *teretifolius* has been submitted to *Molecular Ecology*. Fragmentation has had little impact on patterns of pollen dipsersal among populations, but reduced genetic diversity and changed patterns of pollination within populations resulting in increased correlated paternity in degraded remnants compared to intact remnants.
- Paper on reproductive biology and demography in *C. quadrifidus* ssp. *teretifolius* has been submitted to *Australian Journal of Botany.* Reproductive output was high but highly variable with no relationship to population size, degree of isolation or fragment size. Seedling recruitment was evident in remnants with an intact understorey, but there was consistent widespread failure of seedling and juvenile recruitment in degraded roadside remnants that also showed significant mortality of reproductive adults. In these degraded remnants recruitment failure appears to be the primary cause of species decline.

Management implications

- Ability to rapidly and accurately assess the conservation value of a vegetation remnant is a critical step in landscape management aimed at integrating the goals of conservation and agricultural production. Currently much of this assessment is based on best guesses using anecdotal species-specific evidence, on the general principle that bigger is better and on simple presence and absence data that take little account of long-term remnant trajectories. Improved accuracy of assessment of long-term persistence of broad classes of plant species will facilitate improved prioritisation of remnants for conservation and therefore better allocation of limited management effort.
- Establishment of realistic empirically-based goals for remnant size and landscape configuration that maximise regional persistence of plant species will allow more efficient conservation efforts at the landscape level by facilitating cost-benefit analyses for remnant management and restoration work.

Future directions (next 12 to 18 months)

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

Conservation status and systematics of Western Australian *Acacia*

SPP 2003-008

Team members

B Maslin, J Reid

Context

Acacia species are coming under increasing consideration for utilisation as commercial crops for salinity control and re-vegetation programs, and for their importance in the management of remnant vegetation. Understanding their biology and taxonomy is important if their utilisation is to be sustainable and their conservation effective.

Aims

Undertake research to provide taxonomic and other advice to enable the effective utilisation of *Acacia* for nature conservation and applied purposes.

Summary of progress and main findings

- Herbarium studies were undertaken to progress the taxonomic revision of *Acacia saligna*.
- Curation of the Western Australian Herbarium *Acacia* collections is ongoing and forms the basis for re-assessment of the conservation status of the Western Australian taxa.
- Paper on variation in *A. saligna* presented at a workshop.

Management implications

Identification of *Acacia* species with agroforestry potential will provide options for revegetation programs.

Future directions (next 12 to 18 months)

Complete taxonomic revision of *A. saligna*.

Wattles of the Pilbara

SPP 2004-022

Team members

B Maslin, S van Leeuwen

Context

Acacia is a key genus in the Pilbara, dominating many of the ecosystems across the region. Understanding the taxonomy of *Acacia*, and having the ability to readily identify taxa in this region, is critical to facilitate their conservation and management.

Aims

Produce identification tools, including an interactive CD that will provide easy identification and access to relevant information for Pilbara *Acacia* species in order to facilitate their management and use in nature conservation, rehabilitation and sustainable utilisation.

Summary of progress and main findings

A reassessment of the taxonomic status of *Acacia catenulata* subsp. *occidentalis* was undertaken following examination of specimens of the typical subspecies at the Queensland Herbarium. No taxonomic change was considered necessary (i.e. subsp. *occidentalis* is best regarded as a subspecies, rather than upgrading to species rank).

Management implications

Identification and information dissemination of Pilbara *Acacia* species will facilitate their management and conservation.

Future directions (next 12 to 18 months)

The work on this project is now completed.

Development of interactive identification platforms and content

SPP 2007-014

Team members

K Thiele, C Hollister

Context

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

Aims

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

Summary of progress and main findings

- An illustrated key to all Western Australian species of the family *Goodeniaceae*, which includes important genera such as *Goodenia*, *Dampiera*, and *Lechenaultia*, has been completed and made available to botanists, consultants and interested members of the public on DVD.
- The existing keys to Proteaceae (including *Banksia*, *Grevillea*, *Hakea* and related genera) have been revised and edited, and combined into a single flexible key to all species including those in minor genera.

- A key to all Western Australian species in the family Haemodoraceae (which includes the kangaroo paws and the large and diverse genus *Conostylis*) is under development.

Management implications

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

Future directions (next 12 to 18 months)

- Continue development of the key to Haemodoraceae, correcting errors and making improvements provided from user feedback, and ready the key for final publication.
- Commence interactive keys to further target groups of Western Australian plants.

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

SPP 2009-006

Team members

J Wege, C Wilkins, M Hislop, R Butcher

Context

Western Australia has a rich flora that is far from fully known. New species continue to be discovered through the taxonomic assessment of herbarium collections, floristic surveys and the botanical assessment of mineral leases. There are more than 1,500 putatively new and undescribed taxa in Western Australia, a significant proportion of which are poorly known, geographically restricted and/or under threat (i.e. Threatened or Priority Flora). The lack of detailed information on these taxa makes accurate identification problematic and inevitably delays the Department‘s ability to survey and accurately assess their conservation status.

Aims

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

Summary of progress and main findings

- 15 taxonomic manuscripts on 11 different genera (*Androcalva*, *Commersonia*, *Dielsiodoxa*, *Gompholobium*, *Leucopogon*, *Mirbelia, Petrophile*, *Ptilotus*, *Sida*, *Stylidium*, *Tetratheca*) were published in *Australian Systematic Botany* and *Nuytsia*. Collectively these papers contain descriptive information for 114 taxa, 35 of which are new to science and 40 of which are listed as being of conservation concern. One further manuscript has been submitted for publication and several more are in the advanced stages of preparation.
- Team members collectively provided expert determinations for *c*. 1,650 specimens at the Western Australian Herbarium and field studies resulted in the acquisition of 259 herbarium specimens for the State collection, including 56 collections of new undescribed species and 13 new populations of conservation-listed taxa.
- Three phrase-named taxa were added to Western Australia‘s plant census as a result of taxonomic assessment.
- 14 taxa were added to the *Declared Rare and Priority Flora List for Western Australia*, and two species were nominated for listing as Threatened.

Management implications

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

Future directions (next 12 to 18 months)

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

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

SPP 2009-007

Team members

C Dunne, C Crane, B Shearer

Context

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

Aims

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

Summary of progress and main findings

- Completed the monitoring of the two field trials within *P. cinnamomi* disease centres in native plant communities within Fitzgerald River, Gull Rock and Stirling Range National Parks on the south coast of Western Australia. The first trial investigated the temporal and spatial soil inoculum dynamics of *P. cinnamomi*; the second trial determined the efficacy of the strategic high-concentration phosphite application to reduce autonomous disease centre expansion. *P. cinnamomi* demonstrated significant spatial and temporal variation between and within the three sites due to differences in plant community composition, soil properties, hydrology, topography and climate.
- Monitoring of the *P. cinnamomi* eradication site in Cape Arid National Park continues to indicate successful eradication one year post-treatment. The *in situ* fumigation of the infested zone and localized vegetation destruction has resulted in no recovery of the pathogen across the treated area.
- The containment strategies deployed at Bell Track and Pabelup Drive within the Fitzgerald River National Park required some basic maintenance and the strengthening of containment in some key areas. To date the pathogen is still contained behind the containment lines and many of the novel techniques trialled, including subterranean metham sodium fumigation, root impervious membranes, hydrological engineering controls and strategic phosphite treatment, are proving highly effective.
- Studies were completed into a range of novel control techniques, including soil fumigation using Ethanedinitrile, trialling the efficacy of the high concentration stem application of phosphite in *Banksia grandis* and *Eucalyptus marginata*, and determining the effect of fire retardants on the survival and pathogenicity of *P. cinnamomi*. In brief, the studies found that: Ethanedinitrile is a highly effective fumigant with good potential for use in eradication programs; phosphite injection (5% phosphite) is more effective than stem phosphite application

(10–40% phosphite) in *B. grandis* and *E. marginata*; and the use of fire retardants (e.g. Phos-Chek® WD881) can reduce the risk of spreading *P. cinnamomi* during bushfire management.

- Studies were completed into the application and effectiveness of different hygiene procedures including vehicle and boot cleaning. The study found that: approximately one third of all vehicles inspected were not adequately cleaned; physical scrubbing or the use of a footbath with disinfectant are the most effective methods of cleaning boots; the use of a pressurized spray unit containing 70% methylated spirits is highly ineffective in preventing the spread of the pathogen; and less than one quarter of hikers used the boot cleaning station provided at Sullivan Rock on the Bibbulmun Track.
- Published a review of the catchment approach techniques used to manage a *P. cinnamomi* infestation at Fitzgerald River National Park in *New Zealand Journal of Forestry Science*.

Management implications

- The epidemiology of *P. cinnamomi* varies significantly between the different plant communities across the south-west of Western Australia including forests, woodlands and heathlands. Understanding the factors that affect epidemiology of the pathogen greatly improves predictions for the spread of *P. cinnamomi* and resulting impacts, and allows for site specific management procedures to be developed for defined management goals. Integrated management strategies for specific areas that combine commonly-used and novel control techniques can significantly increase the likelihood of management success.
- A number of novel control techniques were shown to be effective methods for protecting disease-free areas, reducing the rate of spread within partially-infested areas and reducing the impact of the pathogen. The techniques developed also have applicability for the management of *P. cinnamomi* during mining, extractive industries, forestry, road construction, nursery production, horticulture and bushland re-vegetation projects.
- There is a need for a more consistent application of hygiene policies and improved hygiene strategies to reduce the spread of pests, weeds and diseases within Western Australian native ecosystems.

Future directions (next 12 to 18 months)

- Continue to monitor the containment and eradication trial sites.
- Undertake experiments into factors that increase the risk of *P. cinnamomi* spread and the establishment of new disease loci.

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

SPP 2009-008

Team members

J Huisman, C Parker

Context

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

Aims

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

- Incorporate descriptions and images of newly described or recorded taxa of marine flora into FloraBase.

Summary of progress and main findings

- 100 new species descriptions have been uploaded to FloraBase. Genus descriptions for taxa occurring in Western Australia have been finalised for imminent uploading.
- Descriptions of taxa higher than genus (family, order, etc.) are being finalised for inclusion in FloraBase.
- Numerous *in situ* and microscopic images of marine algae have been taken, these will be uploaded to FloraBase as soon as proposed changes to the site are complete.

Management implications

- Easier identification of marine plant species will lead to a more accurate understanding of their conservation status and enhanced knowledge of marine biodiversity will allow a more accurate assessment of management proposals/practices.
- Provision of a readily available web-based information system will facilitate easy access by managers, researchers, community and other marine stakeholders to marine plant species inventories and up-to-date names.

Future directions (next 12 to 18 months)

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

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

SPP 2009-009

Team members

J Huisman, C Parker

Context

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

Aims

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

Summary of progress and main findings

- Continued generation of descriptions and illustrations for the book *Marine Benthic Flora of north-western Australia*. Several individual and collaborative chapters are complete, including *Codium* and *Caulerpa*.
- Participation in a field survey of several central Kimberley locations, resulting in numerous new collections that have included several new taxa, including new species of *Predaea*, *Martensia*

and *Dotyophycus*. In addition, the Kimberley survey resulted in several hundred specimens added to the Herbarium holdings.

- Most recent collections are also represented by material suitable for DNA sequence analyses, many of which have been already been sequenced as part of the 'International BarCode of Life' project.
- Major papers concerning several aspects of the north-western Australian marine flora and revisions to the red algal family Liagoraceae have been published. Papers incorporating significant revisions of the genera *Halymenia*, *Sargassum* and *Caulerpa* have been accepted for publication.

Management implications

- Enhanced knowledge of marine biodiversity allows a more accurate assessment of management and development proposals.
- Easier identification of marine plant species leads to a more comprehensive understanding of their conservation status, recognition of regions with high biodiversity and/or rare species, recognition of rare species, recognition of potentially introduced species, and discrimination of closely-related native species.

Future directions (next 12 to 18 months)

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

Systematics of the triggerplant genus *Stylidium*

SPP 2010-001

Team members

J Wege

Context

With almost 300 known taxa, the triggerplant genus *Stylidium* is one of the most abundant and diversified genera in Australia. Whilst substantial progress has been made over the past 20 years in documenting Australia‘s *Stylidium* diversity, our knowledge of the genus remains insufficient for scientific and conservation needs. There are many new taxa awaiting formal description, numerous species complexes that remain poorly understood, and a number of nomenclature and typification issues that require resolution. Perhaps the most significant issue at this point in time is the lack of an identification guide and readily accessible diagnostic information for the known species in Western Australia, which hinders accurate identification by conservation personnel, botanical consultants and other stakeholders. This is especially concerning in the south-west region where 83 taxa are conservation-listed, the majority of which require further survey to understand the full extent of their distribution.

Aims

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

Summary of progress and main findings

- Field studies were conducted on a range of taxonomically problematic species complexes and vouchers were collected for ongoing systematic research.
- An account of the microgeophytic triggerplants (*S. petiolare* and allies) was completed and published, doubling the number of known species in Western Australia from seven to 14.

- A revision of the ephemeral triggerplants from *S. despectum* and allies was completed and published, resolving considerable confusion in the taxonomic literature and the discrepancies between State floras.
- The identity of almost 500 herbarium specimens at the Western Australian Herbarium was confirmed or corrected. Eight taxa were added to the *Declared Rare and Priority Flora List for Western Australia*.
- Progress was made on compiling data for species fact sheets, an interactive key and several taxonomic manuscipts.
- A preliminary molecular phylogeny of *Stylidium* (140 taxa) has been constructed as part of an ongoing collaboration with researchers based in the United Kingdom.

Management implications

- The publication of descriptive information and identification guides for a suite of tiny triggerplants will assist survey botanists to identify these species, many of which are listed as being of conservation concern.
- Field survey and the correction of misidentified herbarium specimens has improved our understanding of the distribution, habitat requirements and conservation status of a range of triggerplant species.

Future directions (next 12 to 18 months)

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

Taxonomy of selected families including legumes, grasses and lilies

SPP 2011-001

Team members

T Macfarlane, R Cranfield

Context

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

Aims

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

Summary of progress and main findings

- *Wurmbea* (Colchicaceae): paper describing *W. fluviatilis* was published; paper on richness of Wurmbea in rangleands published; further field work in the Midwest, Murchison and the south west has provided considerable material for the description of several new species including distributional and habitat information and photos.
- Hydatellaceae: published paper on molecular phylogenetics of *Trithuria*; review paper on systematics and ecology of Hydatellaceae published.
- Poaceae: Field work obtained plant material for work by external collaborators on molecular, biochemical and cytological work relating to photosynthetic pathway evolution in *Neurachne*. A paper was prepared for submission.

- *Thysanotus*: continued fieldwork and laboratory work, with progress on preparation of papers.
- Bush Blitz surveys: Field and laboratory work resulted in progress on taxonomic reviews of *Arthropodium* and *Tricoryne* but poor seasonal conditions prevented completion.
- *Lomandra*: flowers of undescribed species that have been long-sought were finally obtained and material now available to describe three new species.
- *Eremosyne* (Eremosynaceae): submission of book chapter on taxonomy of this Western Australian endemic, single-species family.
- *Logania* (Loganiaceae): a suspected new species from the south-west forests has led to a review of variation in *L. serpyllifolia*.
- *Brachyloma* (Epacridaceae): A draft paper of a taxonomic revision of a section of the genus is undergoing internal review.
- Work carried out on an interactive key for lichen genera and a representative collection of photos of Western Australian lichen genera was delivered for incorporation into FloraBase. A list of poorly collected lichen species was prepared and submitted for departmental consideration. Fieldwork was conducted in the wheatbelt to investigate the reality of apparent rarity in a number of species and to improve collecting density.

Management implications

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

Future directions (next 12 to 18 months)

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

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

SPP 2011-002

Team members

R Butcher

Context

Tephrosia is a large, pantropical legume genus comprising *c.* 400 species of herbs and shrubs. Sixty taxa are currently recognised in the Eremaean and Northern Botanical Provinces of Western Australia; including 18 phrase-named taxa and five manuscript-named taxa, with a number of species complexes requiring further study. *Tephrosia* specimens are frequently collected during vegetation surveys for proposed mining developments in northern Western Australia; however many of them cannot be adequately identified as they belong to poorly-known, undescribed taxa or to species complexes. Their identification is further hindered by the absence of up-to-date taxonomic keys and of comparable specimens as many species of *Tephrosia* grow in remote areas and are poorly collected. Identification difficulties inhibit the accurate assessment of each taxon‘s distribution and hence its conservation status.

Aims

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

Summary of progress and main findings

- Interstate Herbaria at Brisbane, Melbourne and Sydney were visited and their *Tephrosia* collections studied. Numerous specimens were annotated and redetermined, improving the accuracy of collections in the Australian Virtual Herbarium. Ten taxa occurring in Western Australia were found to be known by different names between Herbaria and some had more than one informal name for each taxon.
- Six additional putatively new taxa have been recognised for Western Australia, two of which are apparently endemic to Western Australia, with the others also occurring in the Northern Territory and Queensland.
- WACensus was updated to remove *T.* sp. *crowded pinnae* as it was the same taxon as *T.* sp. E Kimberley Flora.
- Description of the new species *T. oxalidea* has been prepared.
- Twenty-six specimens of *Tephrosia*, including types for three specifically targeted, putatively new species were collected during field work in the Eremaean. Additional collections included photographs for *FloraBase*, DNA samples for barcoding, and fruiting specimens of species previously collected in flower.
- All *Tephrosia* specimens in the Reference Herbarium have had their identification reviewed, and all taxa for which there is sufficient material are now represented.
- Leaf samples from herbarium specimens of silica-dried plants representing all the *Tephrosia* taxa in Western Australia were sent to the University of Guelph, Ontario, for DNA barcoding. All sampled specimens were also scanned. Sequencing has just been completed, with a success rate of 62% for rbcL and 41% for matK.

Management implications

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

Future directions (next 12 to 18 months)

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

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

SPP 2011-006

Team members

N Lander

Context

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

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

Aims

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

Summary of progress and main findings

- Interactive key to Western Australian Asteraceae genera (183 genera) extended with further binary keys to species.
- Underlying database extended to include new data available in a recently published monograph and other information on the family.
- Papers describing new species of *Pleurocarpaea* and *Pilbara (*a new genus) completed and approved for submission to *Nuytsia.*
- Putative new species of *Olearia* from the Murchison region investigated and shown to be a form of the widespread *Olearia stuartii*.

Management implications

The Asteraceae have a major centre of diversity in Western Australia, with some 583 species (in 187 genera) of shrubs and herbs occurring in virtually every environment. Over 80 are listed as conservation taxa. With the current flux in classification and taxonomy in a group difficult to identify to species level, an authoritative source of current information is fundamental to correctly managing the conservation taxa and the lands on which they occur. Additionally, the Astereaceae are represented in Western Australian by 125 weedy species, some of critical significance.

Future directions (next 12 to 18 months)

- Prepare further papers on taxonomy of *Olearia* and several new related genera.
- Complete interactive key to Western Australian *Olearia* species for incorporation in FloraBase.
- Continue to revise treatment of *Olearia* for new edition of *Flora of South Australia*.

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

SPP 2011-007

Team members

D Coates, M Millar, M Byrne

Context

Acacia woodmaniorum is a recently described species endemic to the Blue Hills banded ironstone ranges of the Midwest region. Known from approximately 29,000 plants and restricted to an area of about 40km^2, the species is gazetted as a Declared Rare Flora. The entire species distribution is currently covered by exploration mining leases, hence potential impacts on population and species viability from proposed mining activities must be identified. Knowledge of genetic structure and gene flow will enable effective management of impacts on this species, and enable understanding of the flora of the banded iron formations.

Aims

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

Summary of progress and main findings

- *Acacia woodmaniorum* maintains moderate genetic structure with an outcrossed mating system and high levels of pollen-mediated gene flow.
- A final report was provided to Karara Mining Ltd and two manuscripts are in preparation for submission.

Management implications

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

Future directions (next 12 to 18 months)

Publication of results will be finalised.

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

SPP 2011-013

Team members

G Keighery

Context

Many Declared Rare Flora (DRF) 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.

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 angustifolum, Adenathos eyeri – A. forrestii – A. ileticos species complex, Cynoglossum, Grevillea curviloba and Grevillea evanescens*.

Summary of progress and main findings

- Paper describing *Grevillea* sp. Gillingarra has been prepared and the species was nominated as Critically Endangered.
- *Picris compacta* has been nominated as presumed extinct.

- Paper detailing native Western Australian plants as weeds is in press.
- Paper reviewing *Calystegia* in Western Australia is in press.
- Paper documenting the occurrence of Scotch Broom in Western Australia is in press.

Management implications

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

Future directions (next 12 to 18 months)

- Taxonomic notes on *Hypocalymma*, *Adenanthos pungens* and *Cynoglossum* to be published.
- Taxonomy notes on *Calytrix breviseta* to be drafted.

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

SPP 2011-014

Team members

K Thiele

Context

This project involves systematic research, particularly resolution of species boundaries and descriptions of new species, in a number of families of Western Australian plants. Describing new species, particularly conservation taxa, is of fundamental importance for conservation, as it provides an underpinning for all other biodiversity research. The families studied in this project include taxa of high conservation and biodiversity significance.

Aims

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

Summary of progress and main findings

- A paper reinstating the rare species *Hibbertia leptopus*, which until 2003 had not been collected for over 150 years, has been published in *Nuytsia*.
- A paper providing a taxonomic assessment and update of all current phrase names in *Eucalyptus* and *Corymbia*, including the removal of 15 phrase names and the creation of eight new phrase names, has been published in *Nuytsia.*

Management implications

Knowledge of species in Western Australia, and the ability to recognise them, is critical for assessing conservation status, prioritising species for conservation management and for conservation planning.

Future directions (next 12 to 18 months)

The taxonomy of *Hibbertia* (Dilleniaceae) remains an important focus of this work, as many new species remain to be described in this large and relatively poorly known genus.

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

SPP 2011-015

Team members

M Hislop, A Chapman, K Thiele

Context

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

Aims

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

Summary of progress and main findings

- Four papers on the genus *Leucopogon* published in *Nuytsia* and one in *Australian Systematic Botany* in which eight new taxa were described and a new combination made. Updated descriptions were also provided for a further five taxa in *Leucopogon.* Seven of these new taxa are now listed as Priority taxa.
- One paper on genus *Dielsiodoxa* published in *Nuytsia* in which three new taxa were described. Updated descriptions were also provided for another three taxa. One of the new taxa is now listed as a Priority taxon.
- A new paper in which a narrower circumscription of *Astroloma* is provided, as well as descriptions of four new species of *Astroloma* has been submitted to *Nuytsia*.
- Collection and re-determination of epacrid specimens in the Western Australian Herbarium, improving the standard of identification in the collection, and veracity of FloraBase output.

Management implications

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

Future directions (next 12 to 18 months)

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

FloraBase and biodiversity informatics at the Western Australian Herbarium

CF 2011-104

Team members

A Chapman, B Richardson

Context

FloraBase, the web information system for the Western Australian flora, is DEC's main means of communicating botanical taxonomic information. Based on three constantly maintained corporate datasets, FloraBase contributes to the global plant information resource and delivers data using international standards, an important issue in an increasingly connected world. Regular updates provide improved access and new features to the site. DEC also delivers biodiversity information through national and international portals, such as the Atlas of Living Australia (ALA) and the Global Biodiversity Information Facility (GBIF). Providing data in a meaningful ways requires the use of agreed data standards created by national and international biodiversity information standards bodies. These standards describe the way in which biodiversity data should be represented and requested by software other than web browsers, and makes it possible to recombine the data in powerful new ways.

Aims

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

Summary of progress and main findings

- Completed initial development of a web tool for harvesting online descriptions from Flora of Australia volumes. Testing prior to a final production rollout is in progress.
- Completed a major upgrade to the maps generation software, resulting in more timely updates, synchronised more closely with WAHerb edits.
- Development of a major upgrade to the way the Herbarium Image Collection is managed is in progress.
- Development of better support for maintaining FloraBase descriptions is in progress.
- A preliminary analysis of the suitability of a reimplementation of WAHerb in Specify 6 indicated that Specify is suitable. However, some issues with it preclude implementation in the short-term.
- Collaborative work with the ALA and other herbaria resulted in the release of a new and greatly improved version of Australia's Virtual Herbarium.
- Work was completed to establish a delivery service (using the international BioCASE standard) to allow specimen records from the Western Australian Herbarium to be delivered regularly and automatically to portals such as the ALA and GBIF.
- A nationally agreed standard and schema for delivering seedbank data was developed, based on the established standard used for herbarium records.

Management implications

- FloraBase continues to provide access to authoritative and accurate information on the State's flora. The community and conservation staff are able to retrieve the most recent information on the name, features, status and distribution of the 13,481 currently recognised native and naturalised Western Australian vascular plant taxa. Consequently, conservation efforts across the State are made more effective by building on quality current data in a readily accessible format from authoritative information systems.
- Continued training in best practice use of FloraBase and vouchering at the Western Australian Herbarium will further aid efficiencies in flora management within the State.
- Involvement in national and international informatics collaborations enables Western Australia to participate fully in new developments in these areas, ensures that Western Australian data is made available to the broadest possible audience, and ensures that data from other sources can be integrated with local data for more effective research and analyses.

Future directions (next 12 to 18 months)

- Implementation of the third major version of FloraBase.

- Deliver taxon descriptions from a wider range of sources, firstly the online *Flora of Australia*.
- Add new content, including interactive keys for identification of plant groups at species level.
- Develop further standards to facilitate and participate in national and international bio-infrastructure projects, such as ALA, NatureMap, and other common online services.

Herbarium collections management

CF 2011-105

Team members

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

Context

The Western Australian Herbarium's collections provide the core resource for knowledge of the State's flora and fungi. The collection is growing constantly, through addition of new specimens representing new taxa and new records of existing taxa. The collection is maintained to a high standard, and provides DEC and the community with the fundamental resource to allow accurate identification of plant and fungi specimens throughout Western Australia.

Aims

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

Summary of progress and main findings

The herbarium collections management program moved the collection into the new Herbarium facility in the Western Australian Conservation Science Centre. Programs were either closed or working at a very reduced level, during this period.

- 7,033 specimens were added to the collection, which now stands at 733,578, a 1% increase in holdings this period.
- The major plant groups in the collection are as follows:

Taxonomic Group	Number of specimens	Increase since June 2011	
	(June 2012)	Number	%
Myxomycetes	815	60	0.01
Fungi	23,273	335	0.04
Lichens	16,291	18	0.00
Algae	23,134	61	0.01
Liverwort and hornworts	1,966	4	0.00
Mosses	6,677	1	0.00
Ferns and fern allies	3,634	33	0.00
Gymnosperms	2,024	11	0.00
Flowering plants	655,742	6,487	0.90
Total number	733,578	7,033	1.00

- Loans and exchange: loans outward—1,090 specimens; loans inward—1,157 specimens; exchange inward—409 specimens.
- Volunteer participation was significant, totaling 6,370 hours.
- Tasks managed by curation staff with the assistance of volunteers were as follows: general curation of specimens; mounting and labeling 5,874 specimens; validation of names and distribution of incoming specimens; auditing, maintaining and adding to the Reference Collection.
- Reference Herbarium: maintained the facility, which has over 14,307 specimens representing 11,531 taxa and also added or replaced 143 specimens. Over 2,000 visitors used this resource to identify plant specimens during this period.
- The Herbarium Identification Program provides identifications to a range of clients and specialises in taxa and specimens that clients find challenging. This year over 3,000 identifications were provided, our most significant clients included DEC, other government agencies, environmental consultancies, Regional Herbaria and the public.
- Documented and implemented an Integrated Pest Management Plan that applies to both the Herbarium and the Western Australian Conservation Science Centre.
- Documented and distributed via DEC website relevant information to help when clients liaise with the Herbarium: Western Australian Herbarium Lodgement Guidelines, Western Australian Herbarium Identification Service, Western Australian Herbarium Visitor Information, Reference Herbarium User Guide.
- Educational role: collaborated with Eco-Education's Bush Ranger Program to provide whole-day activities for secondary school students and teachers; provided training and assessment material for the new Conservation and Land Management training package; provided tours of the Herbarium for tertiary institutions, secondary schools, DEC, environmental consultancies and community groups.

Management implications

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

Future directions (next 12 to 18 months)

- Now that the collection has moved into the new building the Collections Management Program will focus on opening programs closed prior to the move.
- Undertake and complete the scanning of of over 6,000 type specimens as initiated by the Global Plant Initiative to make accessible to the world's scientific community plant type specimens and other botanical resources for study.

The Western Australian Herbarium's specimen database

CF 2011-110

Team members

S Carroll, M Falconer, E McGough

Context

The Western Australian Herbarium's specimen database (WAHerb) allows staff at the Herbarium to manage and maintain the Herbarium's collections, and provides core data on the distribution, ecology and morphology of all taxa for DEC and the community, through the FloraBase and NatureMap

websites. Data from the specimen database is provided to researchers, consultants and community members on request.

Aims

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

Summary of progress and main findings

- 7,033 records were added to the specimen database, including 513 Priority Flora and 58 Threatened Flora.
- 66 requests for specimen data (species lists and label data) were processed for DEC officers, researchers and the public.
- 23,535 specimen records were edited during this period.

Management implications

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

Future directions (next 12 to 18 months)

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

The Western Australian Plant Census and Australian Plant Census

CF 2011-111

Team members

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

Context

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

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

Aims

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

Summary of progress and main findings

- 214 plant names were added to the Plant Census, comprising 135 names formally published and 48 phrase names; 578 other edits were made to the Census, and 51 species were assigned conservation status.

- WACensus updates were regularly distributed to over 241 registered Max users on a quarterly basis.
- Major families processed for the APC were Ericaceae, Cyperaceae and Malvaceae.

Management implications

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

Future directions (next 12 to 18 months)

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

Vegetation Health Service

CF 2011-112

Team members

M Stukely, J Webster, J Ciampini

Context

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

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

Aims

- Provide a dedicated service for the detection and identification of *Phytophthora* species from samples associated with the management of the State‘s forest and conservation estate, logging and mining activities, private industry and research as well as providing a service that is available to external customers on a fee-for-service basis.
- Maintain the VHS‘s live *Phytophthora* Culture Collection and the Western Australia *Phytophthora* database, and continue to make these resources available to researchers and land managers.
- Provide advice to assist departmental personnel, external authorities and the public in dealing with *Phytophthora* dieback and other plant disease problems in parks and reserves, forests and other native ecosystems, plantations and nurseries.
- Facilitate and collaborate in research on *Phytophthora*, both within DEC and externally.
- Monitor MY disease occurrence and spread in Western Australia and conduct trials to investigate mechanisms of spread and conditions contributing to development of MY.

Summary of progress and main findings

- A total of 2,180 samples from departmental and external sources were processed for *Phytophthora* testing, and all isolates of *Phytophthora* spp. (other than *P. cinnamomi*) were subcultured for identification to species. Isolates were identified by DNA sequencing (through CPSM) as necessary.
- The formal descriptions of two new Western Australian species were published: *Phytophthora fluvialis* and *Phytophthora amnicola*. A total of 10 new *Phytophthora* species isolated by the VHS from samples collected in Western Australian natural ecosystems have now been described.
- An invited paper on new *Phytophthora* in Western Australia was published in the special 2012 *Plant Pathogens* issue of *Microbiology Australia*.
- Advice to assist departmental personnel, external authorities and the public has been provided, and input to management plans and manuals was supplied.
- Newly observed MY-affected sites have been checked. Spread of MY symptoms at any given site does not appear to be rapid, and diseased and apparently healthy trees can grow alongside each other. Affected trees have still not been observed within undisturbed forest or woodland stands.

Management implications

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

Future directions (next 12 to 18 months)

- Continue to verify field dieback interpretation for departmental and external clients, by testing soil and plant samples for *Phytophthora*. Provide identification to species level for all *Phytophthora* isolates.
- Continue the DNA sequencing of new *Phytophthora* isolates, as well as historical isolates from the VHS culture collection, through the CPSM.
- Further develop draft recommendations for managing *Phytophthora* other than *P. cinnamomi*.
- Continue monitoring of existing and new occurrences of MY in Western Australia. Grow new seedlings in the glasshouse for MY transmission trials, and harvest foliar material for testing for molecular markers.

Ecophysiology of rare flora restricted to shallow-soil communities

SPP 2012-003

Team members

P Poot

Context

The south-west Australian Floristic Region is recognised as one of only 34 global biodiversity hotspots; those regions on earth richest in endemic species under threat. Approximately 2,000 of a total of 8,000 plant species in south-west Australia occur on granite outcrops or other shallow-soil environments. Many of these species are shallow-soil endemics that have a highly scattered and often restricted distribution. Also worldwide a large number of rare species occur in open, shallow, rocky and drought-prone environments. This suggests that shallow-soil endemics may have special adaptations to their own habitats that prevent them from establishing and being competitive in others. Knowledge of these adaptations will help improve our ability to manage and restore shallow-soil ecosystems and the many rare species they contain.

Aims

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

Summary of progress and main findings

- Published paper on specialized root morphology in *Annals of Botany*.
- Published conference paper on simulation of optimal rooting strategies.

Management implications

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

Future directions (next 12 to 18 months)

- Write up and submit the shallow-soil ironstone species work on phenotypic plasticity.
- Further work on root distribution modelling to better understand how root system morphology and root foraging strategy determine species success in shallow-soil communities and possible failure in others.

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

SPP 2012-004

Team members

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

Context

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

Aims

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

Summary of progress and main findings

- The experimental translocation of the Critically Endangered *Banksia ionthocarpa* subsp. *ionthocarpa* in Kamballup Nature Reserve was monitored. Survival at two years is >70% and some differences amongst combinations of treatments have been identified.
- The experimental translocation of the Critically Endangered *Acacia awestoniana* in the Stirling Range National Park was monitored. This experimental translocation involved different pre-treatments, different microhabitats, and different watering regimes. Survival at two years is >70% and, despite the dry summer, the non-watered plots have not suffered a higher mortality, although they did have reduced growth compared with watered plots. Some differences amongst combinations of treatments have been identified.
- A drought experiment is in preparation in which the drought tolerance of *A. awestoniana* seedlings will be compared with several provenances of two common *Acacia* species.

Management implications

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

Future directions (next 12 to 18 months)

- Analyse the data collected in both species translocations and prepare publications.
- Conduct an experiment to evaluate the vulnerability to drought of *A. awestoniana*.

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

SPP 2012-006

Team members

R Davis

Context

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

Aims

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

Summary of progress and main findings

- One paper published in *Nuytsia* dealing with the infraspecific taxa in *Ptilotus humilis*.
- Descriptions of *Ptilotus* for the *Flora of Australia* treatment almost completed.
- Progressed development of interactive keys to *Ptilotus, Gomphrena* and *Swainsona*.
- Submitted paper on infraspecific taxa within *Adenanthos pungens*.
- Submitted a short communication on the discovery of a presumed extinct species of *Ptilotus.*
- Draft papers on undescribed species of *Solanum, Swainsona, and Ptilotus* have been prepared.

Management implications

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

Future directions (next 12 to 18 months)

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

Understanding mulga

SPP 2012-026

Team members

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

Context

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

Aims

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

Summary of progress and main findings

- A taxonomic revision of Western Australian mulga species was published, with 12 mulga species recognised for Western Australia.
- Scientific publication concerning the identification of the type of *Acacia aneura* submitted for publication in *Nuytsia*.

Management implications

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

Future directions (next 12 to 18 months)

- Undertake mulga identification workshops to facilitate identification of the species.
- Update Western Australian Herbarium Reference Herbarium to ensure that all taxa are adequately represented there.

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

SPP 2012-031

Team members

N Bougher

Context

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

Aims

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

Summary of progress and main findings

- Created databases to stocktake available data for current species concepts and voucher specimens of the ectomycorrhizal fungi family Inocybaceae in Australia.
- Defined morphological and molecular characteristics of seven species of Inocybaceae, including four new species.
- Published journal paper about species of *Inocybe* introduced into Western Australia.
- Produced a key to the genera and major clades of Inocybaceae known from Australia and trialed use of the key at a workshop.
- Completed and reported two fungi research surveys for an external client.

Management implications

The availability of scientifically accurate and comprehensive information about taxa of fungi in Western Australia will encourage and enable a greater uptake and capacity by DEC and community to incorporate fungi in management. This includes regional biological surveys, managing the interdependent linkages between fungi and plants and animals, and a better basis for assessment of the conservation status of fungi taxa.

Future directions (next 12 to 18 months)

- Morphological and molecular phylogenetic data of individual collections of Inocybaceae will be generated and assessed then used to define species concepts.
- Text and illustrative material for each of the defined species will be compiled and formatted for the eventual target product, a monograph of the Australian Inocybaceae for the *Fungi of Australia* series.

LANDSCAPE CONSERVATION PROGRAM

PROGRAM LEADER: LACHIE MCCAW

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

Effects of timber harvesting on terrestrial vertebrates in medium-rainfall jarrah forest

SPP 1993-015

Team members

A Wayne, C Ward, C Vellios, M Maxwell

Context

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

Aims

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

Summary of progress and main findings

- Spotlight monitoring on three standardised transects was maintained at six repeat surveys per transect per year. Ngwayir (*Pseudocheirus occidentalis*) populations in the greater Kingston area declined to almost undetectable levels between 1998 and 2001. One individual was since detected in 2006 and another in 2012. Previously an average of 10–12 individuals (up to 33) were detected per transect per night.
- A review of all available spotlight monitoring data indicates that the decline of ngwayir to almost undetectable levels has now occurred across the entire Upper Warren region. The ngwayir population in the Upper Warren was the largest known population; it is genetically distinct and had higher genetic diversity than Bunbury and Busselton populations.
- Collation and validation of data from previous trapping and spotlighting is complete and up-to-date. Analysis and preparation for publication are underway.
- Two papers on retention forestry have been published that include Western Australian forest management practices in an international context.

Management implications

Information on the impacts of timber harvesting on terrestrial vertebrates will lead to improved ecologically sustainable forest management practices and the conservation of biodiversity.

Future directions (next 12 to 18 months)

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

Fire-induced mosaics in semi-arid shrublands and woodlands

SPP 1993-086

Team members

L McCaw

Context

Shrublands and woodlands are widespread in semi-arid areas of southern Western Australia. Large areas occur on unallocated crown land and in conservation reserves that are sparsely populated and have not been extensively disturbed by pastoralism, mining or clearing. Summer lightning storms regularly ignite wildfires that may burn for months with minimal or no intervention. The spread of fires is determined by the distribution of vegetation types, low-fuel areas such as salt lakes and rock outcrops, and the pattern of past fires. Intense fires can cause long-term changes to the structure of eucalypt woodland communities and in some cases it is difficult to reconcile the long-term persistence of woodlands with the pattern of burning observed over the past few decades. Remote semi-arid lands provide a valuable opportunity to examine natural disturbance regimes that can be compared with more populated and intensively managed landscapes in the south-west.

Aims

- Examine the frequency, intensity and cause of fires in semi-arid landscapes dominated by woodland and shrubland.
- Document the age-class (time since fire) distribution for woodlands and shrublands at a landscape scale.
- Document and interpret the response of vegetation structure to different fire regimes.

Summary of progress and main findings

- A paper on the influence of climatic factors on fire occurrence in semi-arid ecosystems of the Lake Johnson area was published in *Ecosphere*.
- Knowledge gained from the project was used in planning and implementing mosaic burning in the Forrestania area as part of the fire management program for the Great Western Woodlands.

Management implications

Fire managers will be better informed about current fire regimes and the need for active intervention through planned burning or fire suppression, and potential effects of changing patterns of rainfall and temperature in southern Western Australia.

Future directions (next 12 to 18 months)

This project is now complete and will be closed.

Effect of stand density and fertilising on seed-fall. Exp B. Establishment of jarrah (*Eucalyptus marginata*) in shelterwood areas and on dieback 'graveyard' sites

SPP 1993-094

Team members

K Whitford

Context

The availability of a seed crop of appropriate density is a fundamental requirement for the success of shelterwood regeneration following timber harvesting. This study enables more accurate specification and prediction of seed available in stands that are to be harvested to shelterwood specifications.

Aims

- Determine the effect of stand density and fertiliser on the quantity of seed produced in jarrah forests stands.
- Examine seasonal variations in seed-fall.
- Examine the production and loss of buds, flowers and capsules to increase understanding of the seed production cycle.
- Develop a method of estimating the future seed crop of trees from field assessments of these trees.

Summary of progress and main findings

- A manuscript on jarrah seed fall has been submitted for publication in *Australian Forestry*.
- A Science Division Information Sheet on seed fall was produced.
- Data relating tree attributes to seed crop were re-analyzed and an allometric relationship developed to predict seed crops at the tree and stand level.

Management implications

Results from this research have been used to revise the section on seed crop assessment, and in the formulation of Appendix 4 of Sustainable Forest Management Guideline No. 1, 2004 *Silvicultural Practice in the Jarrah Forest*.

Future directions (next 12 to 18 months)

- Finalise publication of manuscript on jarrah seed fall.
- This project is complete and has been closed.

Characteristics of hollow-bearing jarrah (*Eucalyptus marginata*) and marri (*Corymbia calophylla*) trees and coarse woody debris (CWD), their use by selected species of fauna, and the effect of logging-and-burning of jarrah forest on them

SPP 1993-095

Team members

K Whitford, D Feeniks

Context

Hollow-bearing trees and logs are elements of forest structure that are essential for the conservation of hollow-dependent birds and mammals. Developing detailed knowledge of hollows and the attributes of trees and logs that bear these hollows improves DEC's capacity for ecologically sustainable forest management. Studies of standing trees are now complete and current work focuses on hollows in logs on the ground.

Aims

- Describe the size of hollows used by jarrah forest fauna species and the distributions of the sizes, shapes and orientations of these hollows.
- Determine the relationship between tree size and tree age for jarrah and marri and the minimum age and size of trees bearing hollows potentially suited to hollow-dependent fauna species.
- Identify the types of trees and tree crowns that bear hollows and develop predictive relationships for hollow occurrence and abundance.
- Identify fauna species most likely to be threatened by any future shortage of suitable hollows and examine the occurrence of hollows suited to the species most at risk.
- Examine the relationship between the numbers and types of logs and hollows present on the forest floor and site type, forest management and burning history.

- Understand processes affecting recruitment and decay of logs on the forest floor.
- Assemble information on hollow log requirements of various hollow-dependent fauna in the jarrah forest.

Summary of progress and main findings

- A major analysis of the CWD data has been completed.
- Results of this analysis have been presented to Sustainable Forest MManagement Division for consideration during preparation of the draft *Forest Management Plan,* and also to Alcoa and to Worsely Alumina to assist with development of management strategies for CWD in forest areas rehabilitated following bauxite mining.
- The direction of the study has been reviewed and gaps in knowledge required to fulfil the aims of this study have been identified.

Management implications

- Knowledge of hollows and hollow use in the jarrah forest provided the basis for much of Appendix 5 of Sustainable Forest Management Guideline No.1, 2004, *Silvicultural Practice in the Jarrah Forest*, and has been used in the *Jarrah Forest Silviculture Reference Manual*.
- This study has increased awareness within DEC of the functions and importance of CWD in the management of forest ecosystems.

Future directions (next 12 to 18 months)

This project is now complete. A new project focussed on the dynamics of CWD and its role as habitat and as a store of carbon is being developed.

Control of jarrah leafminer: selective retention of jarrah leafminer resistant trees and ground coppice in a demonstration forest plot

SPP 1993-097

Team members

A Wills

Context

Jarrah leafminer (JLM) is an important pest species of jarrah, with significant effects on biomass production. Few management options are available to control JLM. This trial represents, on a small scale, a possible remediation of the impact of leafminer through selective retention of resistant trees by appropriate silviculture practices during tree harvesting operations.

Aims

Provide a visual demonstration of improvement in stand health and productivity by management practices for control of jarrah leafminer.

Summary of progress and main findings

- Sites were inspected, and moderate populations of JLM were found to be present.
- Expression of resistance to JLM was dependent on severity of defoliation.

Management implications

Outbreaks of JLM have abated since the demonstration coupe was established. When JLM next outbreaks in the area, this plot should provide striking visual evidence of the value of selective removal of susceptible stems in reducing population size of the insect.

Future directions (next 12 to 18 months)

- Inspect site annually and carry out coppice removal on treated areas as required.
- This project has been closed and monitoring will continue as part of the project on management of invertebrate pests (SPP 2011-019).

Monitoring long-term effects of various fire regimes on species richness and composition of southern jarrah forest understorey

SPP 1993-099

Team members

N Burrows, B Ward, R Cranfield, G Liddelow

Context

Understanding long-term effects of fire on the floristics and structure of jarrah forests is important for developing and implementing ecologically appropriate fire regimes and for managing fire to protect life and property. This study, established in 1972 in the Lindsay forest west of Manjimup, and in 1986 in the Perup forest east of Manjimup and McCorkhill forest west of Nannup, was designed as a long-term experiment.

Aims

- Understand and quantify the long-term effects of different fire regimes on species richness, composition and structure of the understorey of southern jarrah forest.
- Determine the effects of different fire regimes on tree health and growth rate.

Summary of progress and main findings

- Plant species richness and composition were assessed at Perup and McCorkhill sites.
- A scheduled burning treatment at Perup was not undertaken due to temporary restrictions on prescribed burning by DEC.

Management implications

Based on 20 years of monitoring, there is no indication that regular prescribed burning at 6–10 year intervals, or long periods of fire exclusion, have had any significant effect on tree mortality and growth rate in low-rainfall (~700mm per annum) jarrah forest. Water stress will lead to reduced growth rates so stand density and leaf area index may need to be managed to maintain healthy forests in a drying climate.

Future directions (next 12 to 18 months)

- Analyse all data on the effects of various fire regimes on understorey vegetation and prepare a paper for publication.
- This project is being reviewed.

Increasing productivity of karri regrowth stands by thinning and fertilising

SPP 1993-106

Team members

L McCaw, J Geisel

Context

Thinning to concentrate growth on selected trees is an important component of the silviculture of regenerated karri forest and contributes to achievement of forest structure and productivity goals. Thinning also benefits forest protection by reducing the likely impacts of drought, and facilitating the re-introduction of prescribed fire into regrowth stands. This study quantifies the growth response of a variety of stands on different site types and contributes important information on long-term growth and stand development.

Aims

Provide information about tree and stand growth response to a range of silvicultural treatments that may be applied to even-aged stands of karri regrowth including: thinning from below; fertilising with macro-nutrients and trace elements: and coppice control.

Summary of progress and main findings

Further re-measurement of the thinning experiment in 40-year old karri regrowth forest at Warren block was done in preparation for undertaking a second thinning.

Management implications

Growth response from thinning is factored into scheduled timber yields from the karri forest, and it is important that the magnitude of the response be validated by periodic measurements. Potential losses from *Armillaria* root disease also need to be quantified.

Future directions (next 12 to 18 months)

This project has been closed, and has been incorporated into an updated project to study long-term stand dynamics of regrowth forest in relation to site productivity and climate (SPP 2011-020).

Espacement effects on the development and form of regrowth karri stands

SPP 1993-107

Team members

L McCaw, J Geisel

Context

Karri forest is regenerated following clearfell timber harvesting by planting with nursery-raised seedlings. Initial planting density has important long term effects on the productivity and growth form of regenerated stands. Planting densities were increased during the 1990s in recognition of the fact that some stands planted at 1,250 stems per hectare had poor form with persistent large branches and short boles. Spacing trials are re-measured periodically to assess tree and stand growth, survival and tree form.

Aims

Quantify the effects of initial stocking and espacement on stand growth, tree growth and form of karri planted following clearfell harvesting operations.

Summary of progress and main findings

A report describing the effects of spacing on tree and stand growth, and branching characteristics is in preparation.

Management implications

Current guidelines for planting density in regenerated karri stands appear soundly based, and initial planting densities above 3,000 stems per hectare do not appear to confer any significant improvement in the form of dominant or co-dominant trees.

Future directions (next 12 to 18 months)

- Finalise a manuscript comparing survival, growth and form of planted karri using data from experiments at Nairn and Wheatley forest blocks.
- This project has been closed and has been incorporated into an updated project to study long-term stand dynamics of regrowth forest in relation to site productivity and climate (SPP 2011-020).

Long-term monitoring of impact of timber harvesting on bird populations in south-west forests

SPP 1994-008

Team members

G Liddelow, C Vellios, V Tunsell, M Williams, L McCaw

Context

Understanding the long-term effects of timber harvesting on bird populations in karri and jarrah forests is important for predicting how bird species and numbers of individuals respond in terms of time since regeneration.

Aims

Quantify the effects of timber harvesting and silvicultural practices in karri and jarrah forests on birds.

Summary of progress and main findings

- Completed spring 2011 census in karri forest at Grey and in jarrah forest at Kingston.
- Autumn census at Grey block was not completed because of commitments to fire suppression.

Management implications

The data accrued so far provide an important baseline for assessing future impacts from changing climate, and any associated changes in fire regimes and infection by animal diseases and *Phytophthora cinnamomi*, as well as for evaluating the ecologically sustainable basis of forest management.

Future directions (next 12 to 18 months)

- Undertake autumn census at Grey block in 2013.
- This project is being reviewed.

Project Vesta—prediction of high intensity fire behaviour in dry eucalypt forest

SPP 1997-003

Team members

L McCaw

Context

Successful fire management depends on the ability to reliably predict the behaviour of fires burning under a wide range of fuel and weather conditions. Fire management policy and practice must be underpinned by a sound understanding of fire behaviour so that the most effective and appropriate practices are employed for particular circumstances. This project has addressed recognised limitations in previous fire behaviour prediction models for dry eucalypt forests.

Aims

- Develop a national fire behaviour prediction system for dry eucalypt forests.
- Quantify changes in fire behaviour as fuels develop with age.
- Develop new algorithms describing the relationship between fire spread, wind speed, and fuel characteristics.
- Characterise wind speed profiles in forests with different overstorey and understorey structures.

Summary of progress and main findings

- A paper describing flame dimensions, temperatures and residence times during bushfires in dry eucalypt forest was published in the *International Journal of Wildland Fire*.
- A paper examining changes in fire behaviour as fuel increases with age was published in *Forest Ecology and Management*.
- A paper presenting new fire behaviour models for dry eucalypt forest using visual fuel hazard scores or categorical fuel hazard ratings was published in *Forest Ecology and Management*.
- A paper providing a southern Australian perspective on the use of prescribed fire for fuel management was presented at an international conference held on the theme of Exploring the Mega-fire Reality.

- Field data collected during the 2011/12 bushfire season has verified that the new fire behaviour models predict rate of spread, flame characteristics and spotting distances within acceptable limits of accuracy.

Management implications

Fire managers will be provided with the best available tools to predict fire behaviour to achieve prescribed burning objectives and safe bushfire suppression.

Future directions (next 12 to 18 months)

This project is now complete and will be closed.

Armillaria spread in karri

SPP 1998-006

Team members

R Robinson

Context

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

Aims

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

Summary of progress and main findings

- Research outcomes were summarised for incorporation into the draft *Forest Management Plan 2014–2023*.
- Presentation of research findings and operational control methods was made to the Silvicultural Expert Review Panel.
- Re-assessment of the Warren thinning experiment is progressing.

Management implications

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

Future directions (next 12 to 18 months)

Complete assessment of Warren thinning experiment and analyse 2011/2012 data.

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

SPP 1998-007

Team members

M Byrne, D Coates, S van Leeuwen, S McArthur

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 investigate the mating system and diversity in sandalwood.

Summary of progress and main findings

- *Santalum spicatum*—Analysis of genotypes from 15 natural populations is being finalised. Development of microsatellite markers was published in *Conservation Genetics Resources*.
- *Eucalyptus leucophloia*—Phylogeographic analysis of 20 populations across the Pilbara bioregion was carried out with chloroplast microsatellite markers. High haplotype diversity was found in the Hamersley Ranges and Fortescue River regions indicating these are sites of historical refugia, and low diversity in surrounding areas indicates that they have recolonised in later climatic periods.
- *Acacia ancistrocarpa*—Identification of variable chloroplast DNA sequences has commenced.
- *Aluta quadrata*—Microsatellite markers were developed and genetic analysis was undertaken on samples from eight populations across restricted distribution of the species in the Parraburdoo region of the Pilbara. Genetic diversity was moderate but high population differentiation showed significant genetic structure indicating populations in the three areas have been historically isolated. A report was prepared for Rio Tinto.
- *Acacia atkinsiana*—Collections were made from 16 populations across the Pilbara bioregion. Microsatellites were developed for the species and genetic analysis was conducted using 12 loci. Genetic diversity was low and variable across populations with some populations showing fixation of loci that may indicate historical isolation or recent bottlenecks. Across the species the level of population differentiation was high and some level of geographic clustering of populations was evident, along with some outlier populations. A report was prepared for Rio Tinto.

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

Future directions (next 12 to 18 months)

- Genetic diversity will be investigated in two more species in the Pilbara.
- Phylogeographic patterns will be investigated in *Acacia ancistrocarpa* and *A. atkinsiana*.

The effect of wildfire on forest fungi

SPP 1998-015

Team members

R Robinson

Context

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

Aims

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

Summary of progress and main findings

- Presentation of current results given at the Conservation and Management of Fungi Symposium.
- Monitoring experimental plots for the 15-year post-fire assessment was commenced.
- Two public presentations were given on the response of macrofungal communities to fire.

Management implications

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

Future directions (next 12 to 18 months)

- Continue laboratory work to catalogue and identify voucher specimens collected.
- Commence analysis of data from 15-year post-fire assessment.

State Salinity Strategy wetland monitoring

SPP 1998-018

Team members

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

Context

Substantial biodiversity has been lost across the Wheatbelt Region of Western Australia over the past 100 years. The most pronounced physical changes to wetlands have been associated with native vegetation clearing and salinisation. Broad-scale clearing has more or less ceased but salinisation and fragmentation processes will continue to be expressed for many decades. While it is known that salinisation is a major threat to wetland biodiversity, the relationships between its physical expression and loss of biodiversity are poorly documented and poorly understood. Physico-chemical monitoring aspects of this program began in 1977. Intensive monitoring of fauna, flora, water chemistry and groundwater began in 1997. This is a long term ecological monitoring project.

Aims

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

Summary of progress and main findings

- Fauna monitoring—field component of 2011 monitoring was completed and databased. Archiving of samples from low priority wetlands has allowed some new wetlands within the Drummond and Buntine–Marchagee Recovery Catchments to be added to the program.
- Waterbird monitoring at Lake Warden has shown that a return to low water levels has resulted in return of waterbird communities observed prior to waterlogging.
- Additional sampling of aquatic invertebrates at Lake Bryde was undertaken to assess the effects of a summer flooding event, and additional sampling was undertaken at Drummond Nature Reserve to investigate hydroperiod requirements of aquatic invertebrate fauna.
- Surface water monitoring—depth and water quality monitoring was undertaken at 101 wetlands, and data added to the South-west Wetlands Monitoring Program (SWWMP) database and supplied to managers and external researchers. Continuous water level recorders and rain gauges were installed on several high conservation value wetlands under threat. High resolution oblique aerial photography was obtained for a number of wetlands in the Warren, South Coast and Wheatbelt regions.
- Vegetation monitoring for 2011 was completed. An additional sampling of Lake Wheatfield in the Warden Recovery Catchment was undertaken to capture any response to recent management actions. Preliminary data suggests some recovery of vegetation associated with management intervention to reduce water levels and waterlogging of the riparian zone. Seedling recruitment has also been observed.
- Shallow groundwater monitoring and databasing was completed for the 2011/2012 sampling round. Long-term trends can now be gleaned from the data.
- Report presenting 1977–2010 depth, salinity and pH data for 101 currently-monitored wetlands was completed. A report on the biological monitoring results for Lake Wheatfield in the Warden Recovery Catchment was produced and a report for Lake Bryde is almost complete.

Management implications

- Monitoring of depths, salinities and pH of 101 SWWMP wetlands reveals a number of wetlands are undergoing changes that warrant further investigation and corrective management.
- The long term nature of the project is providing an understanding of the range of variation in biotic communities under different climates and hydrological regimes, and a context in which to assess and predict future changes.
- Surface water management is as important in some Wheatbelt wetlands (e.g. Coomalbidgup Swamp) as groundwater management and a greater focus on surface water is required to maintain wetland health.
- Knowledge of the salinisation effects of rising groundwater and declining rainfall enables prioritisation of conservation efforts in south-west wetlands.
- Hydrological interventions to reduce water levels in waterlogged wetlands, such as implemented in the Warden Recovery Catchment, can be effective at recovering the flora and fauna.

Future directions (next 12 to 18 months)

- Move to more rapid publication of fauna monitoring results through production of brief synopses of results rather than comprehensive reports. The report prepared for Coyrecup Lake provides an example.
- Continue monitoring fauna, flora, groundwater and water chemistry at the intensively managed wetlands, continue continuous water level and rainfall monitoring at selected high value

SWWMP wetlands under threat as a precursor to hydrological modelling, and complete program of obtaining high resolution, oblique aerial photography of all SWWMP wetlands to assist in vegetation mapping, condition monitoring and fauna surveys, and for interpretive purposes.

Management of the Vasse–Wonnerup wetlands

SPP 1999-017

Team members

J Lane, A Clarke, Y Winchcombe

Context

There is a long history of mass fish deaths in the lowest reaches of the Ramsar-listed Vasse–Wonnerup wetland system. The incidence and severity of deaths can be reduced by timely openings of the entrance sandbar and two sets of floodgates. Careful management of flows and water levels is needed to prevent adverse impacts on waterbirds and adjoining lands. Following a mass fish kill in 1997, DEC led the establishment of an inter-agency technical working group to co-ordinate relevant agency activities. This lead role is being maintained.

Aims

- Perform a lead role in the management of water levels, flows and salinities in the Vasse–Wonnerup wetland system.
- Undertake monitoring programs that will enable impacts of Vasse–Wonnerup water level, flow and salinity regimes to be assessed. The principal issues of interest in this project are impacts on waterbird populations and adjoining lands and the occurrence of mass fish deaths.

Summary of progress and main findings

- Monitoring of fish activity and water levels at the floodgates was undertaken. The Vasse estuary floodgate‘s fish gate was opened for periods in summer–autumn to maintain the target water level and to allow fish to pass. The Wonnerup estuary floodgate‘s fish gate was opened periodically to maintain a minimum level sufficient to allow fish to be released if necessary.
- No mass fish kill events occurred in the Vasse estuary, Wonnerup estuary, Deadwater or Wonnerup Inlet during 2011/12.
- A study of historical (pre- and post-1830s) use and management of Vasse–Wonnerup and its floodplain was continued.

Management implications

Water levels and flows are managed throughout the summer–autumn period to minimise adverse impacts on waterbird populations and adjoining lands that could result from excessive water levels and salinity.

Future directions (next 12 to 18 months)

- Monitor estuary water levels during summer–autumn to guide the use of gates for managing these levels.
- Prepare a concise report documenting water levels, floodgate openings, fish releases and mass fish death incidents in the Vasse–Wonnerup system since the December 1997 report.

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

SPP 1999-021

Team members

K Whitford

Context

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

Aims

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

Summary of progress and main findings

- A scientific paper presenting the results from trials on the use of cording to reduce soil compaction was completed and published in *Australian Forestry.*
- A paper examining the intensity, extent and persistence of soil disturbance on FORESTCHECK grids was published in the special issue of *Australian Forestry*.
- Findings from this study were reported in a Science Division Information Sheet.

Management implications

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

Future directions (next 12 to 18 months)

Revise and submit for publication a manuscript on the effects of fire on soil carbon.

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

SPP 2000-003

Team members

J Kinal

Context

This is a long-term experiment established in 1999 to address part of Ministerial Condition 12-3 attached to the *Forest Management Plan 1994–2003*. Ministerial Condition 12-3 states that DEC shall monitor and report on the status and effectiveness of silvicultural measures in the intermediate rainfall zone (900–1,100mm/yr) of the jarrah forest to protect water quality.

Aims

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

Summary of progress and main findings

- Monitoring of groundwater levels, streamflow, stream salinity and stream turbidity in the two treatment catchments and in the control catchment continued.
- Ten years after treatment, maximum groundwater rise, relative to the control, was about 2m in the intensive-treatment catchment and about 1.6m in the standard-treatment catchment.
- Groundwater response appears to have peaked 10 years after treatment in the valleys and hillslopes of the standard-treatment catchment, and in the valleys but not in the hillslopes of the intensive-treatment catchment.
- A manuscript describing the hydrological effect of declining groundwater levels and groundwater disconnection was submitted to the *Journal of Hydrology*.
- Findings from research into streamflow and groundwater in forested catchments were summarised in a discussion paper provided to the Silvicultural Review Expert Panel.

Management implications

- The strong relationship between the magnitude of vegetation reduction and the extent of groundwater rise can guide harvesting and silvicultural practices.
- The risk of increased stream salinity from current harvest and silvicultural practices is lower than with past practices because the prevailing drying climate and retention of more vegetation following harvest results in more subdued groundwater rise than observed in the past.

Future directions (next 12 to 18 months)

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

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

SPP 2001-005

Team members

A Wills, J Farr

Context

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

Aims

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

Summary of progress and main findings

Progress with data analysis was continued.

Management implications

The finding of high beta-diversity at small geographical scale (tens to a few hundred metres) within valley geomorphic units expands on the findings of other studies in the jarrah forest that show broad

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

Future directions (next 12 to 18 months)

- Update database and analyse the combined dataset.
- Write up and publish results in a refereed journal.

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

SPP 2003-003

Team members

P Van Heurck, Frankland District staff

Context

Tall tingle and karri forests contain a high proportion of short-range relict invertebrate species. In March 2001, a wildfire in the Nuyts Wilderness near Walpole provided an opportunity to assess the impact of high-intensity fire on the species composition of invertebrate communities. Species composition was also compared with relict invertebrate communities in prescribed-burnt and long-unburnt tall forests. Understanding effects of a single intense fire on invertebrate biodiversity is important for developing and implementing ecologically appropriate fire regimes and for managing fire for community protection.

Aims

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

Summary of progress and main findings

- Contrasting fire regime impacts were compared and confirmed by both LANDSAT remote sensing and on-ground measurement at each site. Analysis showed that a severe wildfire markedly reduced the heterogeneity of measured forest structural and habitat attributes in all forest strata. In contrast, structural heterogeneity increased following each of the three patchy fine-grained mosaic burns.
- A large proportion of the beetle morphospecies in this assemblage have each only been collected from a narrow niche within and between wildfire and mosaic fire regimes. The greater habitat and patch fire-age heterogeneity of the mosaic regime sites has a higher richness of fire niche-specific beetle species.

Management implications

- The Nuyts Invertebrate Collection contains a large proportion of invertebrate species previously undescribed from old growth forests of the Warren bioregion. The occurrence of species within a wide range of fire ages surveyed provides fire managers with important conservation information on a large segment of the local biodiversity, including short-range endemic taxa.
- Making high resolution images available on a website for the use of international taxonomists has facilitated rapid identification of reference collection morphospecies.
- The prodromus of beetle morphospecies collected from the Mt Roe National Park provides a basis for comparison with other ecosystems and assessment of disturbance.

Future directions (next 12 to 18 months)

- Analyse how the beetle species of the Mt Roe National Park assemblage have responded to different fire regimes across all three components of biodiversity (taxonomic, structural, functional).
- Establish monitoring for declared threatened invertebrate species within tingle forest communities across a mosaic of vegetation types and fuel age.
- Future resampling of the karri invertebrate ecosystems will allow meta-data comparisons with the jarrah ecosystem complexes of the Fine-Grain Mosaic project, and provide eco-education opportunities forlocal volunteers.
- Local inventories will be incorporated into the state-wide BugBase inventory for meta-analysis of south-west invertebrate fire ecology.

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 (see also Rangelands Restoration—reintroduction of native animals to Lorna Glen in Fauna Conservation Program section of this report)

SPP 2003-004

Team members

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

Context

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

Aims

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

Summary of progress and main findings

- A successful feral cat, fox and wild dog aerial baiting and trapping operation was carried out again in 2011 as part of the Western Shield program. Feral cat density on Lorna Glen is being sustained at ~25% of the potential density in the absence of control measures. Exceptional rainfall over the last 18 months could see an increase in introduced predator density.
- Quarterly predator surveys were carried out. Feral cat track activity remains low with the track density index (TDI) 8–11.4 (from a pre-treatment high of >30). A draft manuscript summarising introduced predator work at Lorna Glen over the last six years has been submitted for publication.
- Biodiversity monitoring sites (BioMonitoring) were re-assessed. Species diversity and capture rates were relatively high, reflecting predator control and good rainfall.
- Mulgara (*Dasycercus cristicauda*) population size has increased dramatically with mulgara being found across virtually all landform systems and in all ages of spinifex.
- The new fire management plan was implemented, including installation of fuel reduced buffers around the compound and around some of the fire management cells.
- The 1,100 hectare predator-proof acclimatisation compound has proven to be highly successful. There have been no further predator breaches and animals in the compound are thriving.
- Bilby (*Macrotis lagotis*) were reintroduced about five years ago and six volunteers on horseback were used to monitor their activity over ~36,000 hectare to obtain information on density and distribution. The monitoring was very successful with an estimated bilby population of 130–300 animals, suggesting that bilbies are persisting but population growth is slow.
- Commenced research into the value of ecosystem engineers.
- Golden bandicoots (*Isoodon auratus*) were released outside the compound.

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 arid zone rangelands mammals, other extant fauna, vegetation and other elements of the biota will provide reconstruction of animal and plant assemblages in an arid zone ecosystem.
- A framework and protocol for assessing and reporting trends in ecosystem condition in arid zone rangelands will provide a basis for ecosystem condition monitoring.

Future directions (next 12 to 18 months)

- Implement and assess the effectiveness of the annual feral cat, wild dog and fox baiting program.
- Monitor the success of mammal reintroductions.
- Implement buffer and patch-burning according to the fire management plan.
- Continue monitoring extant fauna and assessment of condition of vegetation.
- Write up research findings about the role of mammals as ecosystem engineers.

Management of environmental risk in perennial land use systems

SPP 2004-003

Team members

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

Context

The development of perennial-based land use systems for management of dryland salinity promises significant environmental and economic benefits, but there are also risks to existing natural biodiversity. These risks include the establishment of new plant species as environmental weeds, hybridisation with native species and gene flow from cultivated populations into natural populations.

Aims

Develop and implement procedures for management of environmental risk in the form of assessment and management protocols to be applied to all germplasm under development within the Future Farm Industries Cooperative Research Centre (FFI CRC).

Summary of progress and main findings

- Weed risk assessments have been completed for nine exotic and native forage and woody species and are published online at the FFI CRC website; two additional assessments are nearing completion. A process to prioritize other species for weed risk assessment is underway.
- Genetic risk assessment protocol was developed and published in the *Journal of Applied Ecology*. The protocol is published on the FFI CRC website and a template is available for research personnel. A case study has been completed.
- Continued involvement in national discussions on improvements to weed risk assessment including contributions to the review of the national post-border weed risk management protocol.
- Journal paper on the genetic structure in *Atriplex nummularia* and genetic differentiation between subspecies has been published in *Biological Journal of the Linnean Society*.
- Format for species management guide for land holders was finalised and the guides for the four species have been published on the FFI CRC website. An additional guide is in preparation for publication.
- Guidelines for planning and management of experimental trial sites have been completed and published on the FFI website.
- Paper on genetic identification of weedy populations of *A. saligna* in South Australia has been accepted for publication in *Australian Journal of Botany* and a paper on genetic analysis of *A. saligna* in South Africa has been published in *Molecular Ecology*. Two papers on genetic and ecological aspects of invasive acacias were published in a special issue of *Diversity and Distributions*.
- Paper on genetic contamination of *A. saligna* remnants from a planted stand has been published in *Restoration Ecology*.

Management implications

- Promotion of the concepts of weed and genetic risk management both within and outside the FFI CRC and the development and use of appropriate assessment techniques will reduce the risk of large-scale plantings of new perennial species or newly developed cultivars becoming environmental weeds.
- Increased knowledge of gene flow will provide information for the genetic risk assessment process and enable the risk of genetic contamination and hybridisation to be assessed.
- Guidelines and risk assessment will inform species selection and trial and planting plans to minimise the risk of agriculturally useful species to native environments.

Future directions (next 12 to 18 months)

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

- Publish research into flower and fruit production in *A. saligna*.

Burning for biodiversity: Walpole fine-grain mosaic burning trial

SPP 2004-004

Team members

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

Context

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

Aims

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

Summary of progress and main findings

- Biodiversity monitoring sites were re-assessed.
- The standard fuel reduction burn treatment was implemented by Frankland District.
- Two new sites in long-unburnt vegetation were installed in London block to fully represent the diversity of the mosaic.
- Fuel age mosaic maps, including for Surprise east, were updated from satellite imagery.

Management implications

The study demonstrates that fine-grain patch-burning is operationally feasible in forest areas. The benefits to biodiversity are yet to be fully assessed—this will take time to emerge.

Future directions (next 12 to 18 months)

- Sample grids will be assessed in spring 2012, after which data will be analysed and written up.
- No further field work will be undertaken until the 10-year project review is completed.

Monitoring post-fire effects from the 2001 Nuyts wildfire

SPP 2006-001

Team members

G Liddelow, B Ward, R Cranfield, P Van Heurck, L McCaw, Frankland District staff as required

Context

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

Aims

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

Summary of progress and main findings

- Data on tree mortality, eucalypt regeneration, shrub regeneration and bird population responses have been analysed.
- Bird census data for the five years following fire have been summarised.

Management implications

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

Future directions (next 12 to 18 months)

Manuscript on recruitment of eucalypt seedlings will be submitted for scientific publication.

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

SPP 2006-002

Team members

M Pennifold, A Pinder, K Quinlan

Context

The *Forest Management Plan 2004–2013* includes a range of key performance indicators (KPIs) based on the internationally agreed Montreal Protocols. KPI20 is the percentage of water bodies (e.g. stream kilometres, lake hectares) with significant variance of biodiversity from the historic range of variability. This project addresses this KPI by monitoring aquatic invertebrates in representative stream sites within the jarrah and karri forests of south-western Australia, particularly in relation to forest management practices.

Aims

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

Summary of progress and main findings

- Seventh round of annual sampling was conducted in spring 2011 and all samples were processed ready for invertebrate identification. Some sites had low water flow during early sampling so were re-sampled after more substantial flows.
- Invertebrate identifications were completed for the 2010 samples.
- Annual logging and fire histories of all 50 catchments were updated in a GIS environment for the period from 2000–2011.
- A report on KPI20 was prepared for inclusion in the End of Term Audit of the *Forest Management Plan 2004–2013*.

Management implications

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

Future directions (next 12 to 18 months)

- Identify invertebrates collected during the 2011 sampling.
- Undertake limited stream sampling in spring 2012 in areas burned by the 2011/2012 summer fires in the Warren Region.
- Continue to update fire and logging history for catchment areas.
- Work with Sustainable Forest Management Division to develop a program of monitoring and research for the *Forest Management Plan 2004–2013*.

FORESTCHECK—integrated site-based monitoring of the effects of timber harvesting and silviculture in the jarrah forest

SPP 2006-003

Team members

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

Context

FORESTCHECK is a long-term monitoring program and results will be used by forest managers to report against Montreal Process criteria and indicators for Ecologically Sustainable Forest Management. Initiated as a Ministerial Condition on the *Forest Management Plan 1994–2003*, FORESTCHECK has been incorporated in the *Forest Management Plan 2004–2013* as a strategy for increasing knowledge on the maintenance of biodiversity and management effectiveness in Western Australian forests.

Aims

Quantify the effects of current timber harvesting and silvicultural practices in the jarrah forest (gap creation, shelterwood, post-harvest burning) on soils, macrofungi, cryptogams, vascular plants, invertebrates, terrestrial vertebrates and birds.

Summary of progress and main findings

- Eleven grids in Blackwood district were re-measured with data collected for cryptogams (lichens, liverworts and mosses), macrofungi, vascular plants, invertebrates, terrestrial vertebrates, birds, litter and stand structure (basal area and stocking of overstorey species).
- The 2010/2011 annual report for grids in the Wellington District was completed. Findings were presented at Collie in December 2011.
- Ten research papers presenting results of analysis from the first five-year monitoring period were published in a special edition of *Australian Forestry* (Vol. 74 Issue 4) in December 2011.
- Few significant impacts of silvicultural treatments (gap release and shelterwood/selective cut) were evident, with most species groups appearing to be resilient to the disturbances imposed.
- Lichens were the most sensitive group to short-term (<10 years ago) disturbance.
- Results from the five-year analysis were presented in public seminars held in Denmark (Western Australia) and Brisbane (Queensland).

Management implications

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

Future directions (next 12 to 18 months)

- Determine directions for future monitoring.
- Analyse and present results from monitoring in the Blackwood District.
- Commence analysis of data from the 10-year monitoring period (2002–2012).

Identification of seed collection zones for rehabilitation

SPP 2006-008

Team members

M Byrne, D Coates, S McArthur

Context

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

Aims

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

Summary of progress and main findings

- Preliminary analysis of genotype data from *Kennedia coccinea* shows some genetic structure with populations in the north-eastern edge of the range, at the Porongurups, and at Lake Clifton showing clear divergence from the main forest populations. Southern jarrah-karri forest populations also showed some divergence from the northern jarrah forest.
- Preliminary analysis of genotype data from *Allocasuarina humilis* shows little genetic structure throughout the south-west forests, but some divergence of populations in the Cape Arid area and an isolated population on the south coast.

Management implications

Knowledge of genetic structure and local adaptation will enable identification of appropriate seed collection zones for rehabilitation of forest areas in order to maintain the genetic integrity of the forest on a sustainable basis. Current data on *Kennedia coccinea* and *Allocasurina humilis* indicate seed collected from the same landscape conservation 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 conservation unit then use of seed from nearby areas in adjacent landscape conservation units would also suffice.

Future directions (next 12 to 18 months)

- Further data analysis undertaken for *Bossiaea ornata.*
- Genetic analysis of phylogeographic patterns in *K. coccinea* and *A. humilis* will be undertaken.
- Species for further analysis will be selected based on priorities for forest rehabilitation and to represent species with different life history traits.

Bushfire Cooperative Research Centre Project 1.4: Improved methods for the assessment and prediction of grassland curing

SPP 2007-007

Team members

L McCaw

Context

Grassland curing has a significant effect on bushfire behaviour, particularly the development and subsequent rate of spread of a fire. Australian and New Zealand fire behaviour models and fire danger rating systems require grassland curing as an input to predictions of fire danger and fire spread. Outputs from fire danger rating systems are used by fire management agencies to determine fire danger and to aid in fire management activities such as determining fire season status, resource allocation and the imposition of restrictions on activities. These decisions can have significant economic and social impacts on local communities. Similarly, predictions of rate of spread and headfire intensity based on grassland fire behaviour models assist in fire suppression decision-making, and in decision-making about prescribed burning. The degree of curing is currently assessed visually or by satellite remote sensing using an index based on the reflective properties of grasses at different wavelengths. Improved techniques for estimation of grassland curing are particularly important for implementing fire management programs in remote areas of northern and interior Western Australia.

Aims

- Extend current grassland curing field data across Western Australia so that improved methods for the assessment and prediction of grassland curing are robustly applicable over a wide range of grassland types.
- Develop and validate improved methods for assessment and prediction of grassland curing by establishing sampling sites representative of the major grasslands of Western Australia, and collecting and analysing grassland curing data from major grasslands.

Summary of progress and main findings

Data from the project have been archived.

Management implications

Development of methods for assessing and predicting current and future levels of curing in grasslands, focusing on two main areas, remote sensing applications and pasture (grass) growth modelling, will allow improved predictions of fire behaviour.

Future directions (next 12 to 18 months)

The project is now complete and will be closed.

Fire regimes and biodiversity decline in the Kimberley

SPP 2007-008

Team members

I Radford, R Fairman

Context

Recent studies in the Northern Territory have shown declines for some elements of savanna biodiversity. Biodiversity declines in otherwise intact landscapes have been attributed to increased intensity and frequency of fires. Studies in central Australian arid environments have highlighted the strong influence of fire, combined with introduced predators, on fauna abundance. This evidence from both the tropical savannas and arid environments has implications for northern Western Australia, including the Kimberley where there have been major shifts in fire regimes. A direct link between abundance of threatened animals and fire regimes in the Kimberley has yet to be established. This study will establish whether fire has a strong influence on abundance of savanna fauna in the north

and east Kimberley. It will address the question of how fire regimes influence critical weight range (CWR) mammals, reptiles, frogs and invertebrates by analysing vegetation structure and resource dynamics in association with changes in abundance.

Aims

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

Summary of progress and main findings

- The first four-year phase of this study in the north Kimberley is complete, with a number of papers published in scientific journals.
- Small-scale fires were found to have little direct influence on the abundance of mammals or other fauna. However, changes in diet selection among predator/insectivorous mammals after fire, mediated by removal of ground layer vegetation, shows a trophic effect of fire on savanna food webs. Fire promotes increased success among predators in catching and ingesting larger prey items. This has implications for introduced predator impacts on fauna after large-scale fires. Top-down predation by cats and dingoes may drive fire impacts on mammals after large-scale fires.
- Resource limitation due to fire is not a tenable explanation for fauna decline as resources for insectivorous and predatory species recover rapidly after fire.
- Despite large post-fire changes in the structure of pindan woodland few changes in pindan fauna were detected. Species information, and lack of fire responses among most groups, shows that fauna in this vegetation type do not differ from that in surrounding savannas, and that this fauna is relatively resilient to most fire regimes. Large *Ctenotus* skinks and larger rodents showed a preference for long-unburnt vegetation (>4 years post-fire).
- Despite *Callitris* being an indicator of low intensity fire regimes, this iconic species does not appear to confer fire shelter to other fire sensitive flora or fauna. Although *Callitris* stands had different vegetation structure relative to surrounding savannas, they were not associated with a greater proportion of fire sensitive plants (obligate seeding, heath or vine thicket species), CWR mammals, large *Ctenotus* skinks or forest-associated ant species. *Callitris* stands are therefore not useful foci for conservation of fire-sensitive flora or fauna in savanna landscapes.

Management implications

Persistence of CWR mammals will be favoured by fire mosaics with small burn patch size (<1km^2) and retention of long unburnt patches of vegetation across the savanna landscape. While this may be difficult to achieve at a regional scale due to resource constraints, target management areas could be established for application of fine-grain mosaics locally to test for their conservation benefits. Evaluating biodiversity outcomes of DEC fire management operations is crucial within an adaptive management context to avoid mammal community collapses that have occurred elsewhere in northern Australia.

Future directions (next 12 to 18 months)

This project has led directly to the development of monitoring and evaluation for the Kimberley Science and Conservation Strategy Landscape Conservation Initiative in the north Kimberley. This will be covered under the new SPP 2012-027.

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

SPP 2007-009

Team members

M Stukely

Context

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

Aims

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

Summary of progress and main findings

- Initial tree and mid-storey plant measurements were completed on the newly established permanent trials at six sites in Cobiac Block in the Wungong Catchment. These six trials are on sites that represent different thinning regimes, dieback status and topographic positions.
- Extra replicate blocks were pegged in one trial.
- Initial canopy assessment using hemispherical digital photography has been completed on all six sites.
- Permanent back-up tagging to identify all trees for long-term monitoring is progressing.
- Dieback disease fronts adjacent to these sites have been permanently marked to allow long-term monitoring and measurement of disease spread upslope, downslope and across slope under different conditions.

Management implications

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

Future directions (next 12 to 18 months)

- Complete initial crown health assessment and tree measurement on the first six trials, and analyse data.
- Carry out eucalypt and mid-storey regeneration assessments.
- Permanently mark additional dieback fronts for long-term monitoring and measurement of disease spread under different site conditions.
- Continue site selection and establishment of trials representing different Havel forest site types, thinning regimes, dieback status and topographic positions.
- Carry out initial assessments and measurements on the new trials and commence second measurements and assessments as appropriate on the earliest trials.

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

SPP 2009-005

Team members

C Yates, C Gosper, S Prober (CSIRO)

Context

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

Aims

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

Summary of progress and main findings

- Assessment of vegetation community composition and structure across a time-since-fire gradient showed that tallerack mallee-heath decline in species richness and senescence when long-unburnt (>50 years post-fire), whilst mallee does not. A paper arising from this work was published in *Austral Ecology*.
- Plant functional types (PFTs) defined by fire response traits were found to be useful for predicting and generalising vegetation changes with time since fire in mallee-heath, a shrubland community dominated by serotinous non-resprouting species. The predictive ability of PFTs in mallee, a community dominated by serotinous resprouters, was lower. A paper from this work is in press in the *Journal of Vegetation Science*.
- Measurement of vital attributes (mortality and fecundity) for selected species with contrasting fire life-histories showed that some serotinous species take 20–30 years post-fire to accumulate a substantial seed bank, but some obligate seeding species have high mortality in long-unburnt (>50 years) vegetation. A manuscript from this work is under review.
- A paper on the bird communities of the Lake Magenta, Dunn Rock and Lake King Important Bird Areas was published in the *Australian Journal of Field Ornithology*.
- Papers were presented at the Bushfire Research Forum and an international conference.

Management implications

The research will inform ecological fire management of nature reserves and other remnant vegetation in the Wheatbelt and South Coast regions.

Future directions (next 12 to 18 months)

Complete publication of scientific manuscripts and information sheets arising from this work.

Monitoring the northern extent of jarrah leafminer outbreak

SPP 2009-010

Team members

J Farr, A Wills

Context

Jarrah leafminer (JLM) is an important pest species of jarrah, with significant effects on jarrah biomass production and forest ecosystem health. Monitoring the incursion of JLM infestation into highly productive areas of jarrah informs management of those areas and assessment of standard management practices on the spread of infestation.

Aims

- Monitor and document the northern extent of JLM outbreak in jarrah forest.
- Provide warning of change in forest health and productivity caused by incursion of JLM into as yet unaffected forest.

Summary of progress and main findings

Leafminer populations and leaf miner mortalities were surveyed along a transect south of Dwellingup in October 2011, and no northward movement of infestation was detected.

Management implications

Biomass productivity of jarrah and forest ecosystem health in the northern jarrah forest is presently unaffected by JLM.

Future directions (next 12 to 18 months)

- Prepare a five year progress report on extent of JLM infestation in the northern jarrah forest.
- Conduct October 2012 census of JLM infestation at 48 FORESTCHECK sites.
- This project will be closed and monitoring continued as part of the project on management of invertebrate pests (SPP 2011-019).

Fire regimes and impacts in transitional woodlands and shrublands

SPP 2010-011

Team members

C Yates, C Gosper, S Prober (CSIRO Ecosystem Sciences), G Wiehl (CSIRO Ecosystem Sciences)

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 comprises the largest and most intact area of contiguous temperate woodland remaining on Earth. The GWW Conservation Strategy and a review conducted by a wide range of scientists with expertise in the region each identified inappropriate fire regimes as a threat to the woodlands and emphasised the need for a science-based fire management regime for the area. Critical gaps in the knowledge of fire ecology for GWW woodland ecosystems are a major hindrance for ecological fire management in the region. The GWW supports eucalypt woodlands at very low mean annual rainfall (250–350mm), which require fire to establish but are very slow growing. In recent decades a large part of the GWW has been burnt and concern has been expressed over the ecological impacts of this. Fire ecology research already undertaken in eastern wheatbelt nature reserves under SPP 2009-005 will help resolve ecological fire management issues for mallee and mallee-heath communities in the GWW, but similar information for the dominant eucalypt woodlands is urgently needed.

Aims

- Investigate the effects of time since fire on the assembly and recovery of gimlet (*Eucalyptus salubris*) woodland composition and development of ecosystem structure.
- Measure fuel dynamics with time since fire in gimlet woodland, mallee and *Allocasuarina* shrubland.
- Investigate pathways to weed invasion in the GWW.

Summary of progress and main findings

- A review conducted by a wide range of scientists investigating options for facilitating adaptation of biodiversity to climate change in the GWW was published in *Climatic Change*.
- Plant species richness, community composition and vegetation structure were sampled at 20 new sites in gimlet woodland across a time-since-fire gradient ranging from two years post-fire to long unburnt (bringing the total number of sites sampled to 72). Sample identification has been completed and data analyses are ongoing.
- Investigations of dendrochronology and the relationship between size and age for gimlet were completed at 72 sites across the time since fire gradient. Models of plant size and age were robust, allowing estimation of the time since fire for woodlands burnt >50 years ago where remote sensing is not available to determine the time since fire. A draft manuscript and information sheet on this research has been prepared.
- Forty-eight sites have been assessed for fuel dynamics.

Management implications

The research will inform ecological fire management that will benefit the outstanding natural values of the GWW.

Future directions (next 12 to 18 months)

- Complete analyses to describe how gimlet woodlands change in composition, diversity and structure with increasing time since fire.
- Complete fuel assessments.
- Compile data layers and undertake analyses to identify drivers of weed invasion into GWW ecosystems.

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

SPP 2011-019

Team members

J Farr, A Wills, P Van Heurck

Context

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

on the biological aspects of forest health threats by invertebrates in the south-west of Western Australia.

Aims

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

Summary of progress and main findings

- Populations of GLS in 2010/2011 defoliated more than 250,000 hectares. Populations have decreased overall since 2010/2011 from 824 to 608 larvae/kg dry weight of leaf; however, the insect is still in outbreak with some areas having increased GLS and some decreased populations. Pheromone trapping has been successful and proves to be a useful future tool in forest health surveillance. A regression is being developed to relate moth numbers caught in pheromone traps to relative larval numbers in the canopy. Furthermore, satellite imagery and GIS have a strong correlation with aerial surveillance, although fire events can confuse the data.
- Pathological elements have been found in populations and suggest jarrah is usually a marginal host for GLS, which restricts its development into a bivoltine population and under normal conditions results in low populations. GLS grows larger on marri.
- A paper on the use of pheromones to trap adult moths has been accepted for publication in Australian Forestry.

Management implications

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

Future directions (next 12 to 18 months)

- Continue monitoring population levels of GLS on established sites.
- Quantify JLM levels on FORESTCHECK sites.
- Refine relationship between pheromone captures and larval numbers for GLS, and develop quantification of leaf area index and relate this to GLS population levels.
- Further develop the relationship between defoliation rates, leaf area index and satellite imagery.

North Kimberley Landscape Conservation Initiative—Monitoring and Evaluation

SPP 2012-027

Team members

R Fairman, I Radford

Context

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

savannas. This monitoring and evaluation program will provide a report card on performance of landscape management initiatives in the north Kimberley, particularly prescribed burning and cattle culling, in maintaining and improving biodiversity status.

Aims

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

Summary of progress and main findings

- LCI monitoring and evaluation sites were established and measured for mammal abundance, vegetation structure and rainforest species at King Leopold (n=12) and Mitchell River national parks (n=35), and in adjoining areas.
- Mammal status at both King Leopold and northern Mitchell River national parks in 2011 was improved or maintained compared with historical survey records from 1981–1982, 2003–2004, and the period from 2007–2010. The diversity and abundance of mammals was much lower in more inland areas of the Mitchell River National Park, where cattle density is higher and the incidence and frequency of fire since 2000 has been greater.
- Higher populations of threatened *Conilurus penicillatus* were detected in the Lone Dingo and Surveyors Pool areas of the northern Mitchell River region, where cattle have been culled over the last four years. This is strong evidence of negative effects of cattle on this species.
- No obvious relationship was found between vegetation ground cover, time since fire and critical weight range mammal diversity or abundance, despite theoretical predictions. This suggests that site specific vegetation attributes have little direct influence on mammal abundance. Larger scale landscape attributes, for instance pattern of unburnt patches over tens of kilometres, may have greater influence on site specific abundance.
- Dingoes were common throughout the King Leopold and Mitchell River national parks, irrespective of mammal abundance. This suggests that dingoes do not have a strong negative impact on small mammal populations, and in fact may have a net positive effect through suppression of cat predation. Few cats were recorded in either area, although they were more often seen at southern Mitchell sites where mammal abundance and diversity was lower.

Management implications

- There is strong evidence that cattle have negative influences on critical weight range mammals, including threatened species such as *Conilurus penicillatus.* Culling programs should therefore be maintained and expanded in important conservation reserves.
- A regime of prescribed burning with small patch size (<1km^2) will contribute to reducing the extent of late-season bushfires, and maintain low fire intensity, a higher density of tree hollows, higher local occurrence of ground cover vegetation and key resources including grass seeds.
- Dingoes can contribute to the conservation of small mammals, and baiting should be avoided in conservation areas.

Future directions (next 12 to 18 months)

- Monitoring and evaluation will be continued so that the effectiveness of management interventions can be evaluated.
- Collaborative monitoring programs will be expanded to incorporate adjoining areas on pastoral lease and Indigenous-owned land, to provide comparative data on mammals and vegetation trends where cattle populations remain high and fire regimes are not managed.

MARINE SCIENCE PROGRAM

PROGRAM LEADER: CHRIS SIMPSON

The broad goal of the of the Marine Science Program is to ensure DEC's marine biodiversity conservation and management programs are based on good science. Specifically, the program promotes and undertakes marine research and monitoring to improve the scientific basis for the conservation and management of Western Australia's state-wide system of marine protected areas, threatened marine fauna and marine biodiversity generally. The program also coordinates and manages external marine research programs, such as the current investigation into the ecology of the Ningaloo Marine Park that is undertaken as part of the Western Australian Marine Science Institution.

The research and monitoring programs undertaken by the Marine Science Program are based around the research and monitoring strategies identified in protected area management plans and threatened species recovery/management plans, ensuring that all activities are clearly linked to departmental priorities and programs.

Conservation of marine turtles in Western Australia

SPP 1993-040

Team members

B Prince

Context

All marine turtles found in Western Australian waters are listed as threatened species by the Commonwealth of Australia and the state of Western Australia. Currently turtle research and monitoring in Western Australia is undertaken by DEC Science Division and regional staff, academics and industry consultants, with limited standardisation of methods or integration of data. There has also been a significant increase in turtle research in Western Australia by external scientists as a result of the potential impacts on these species from industrial development. A comprehensive review of all (internal and external) historical and current turtle research and monitoring is needed to underpin the development of an integrated state-wide approach to turtle research and monitoring in Western Australia.

Aims

- Provide critical scientific information for the conservation of marine turtles in Western Australia and the management of human pressures on these animals.
- Gain an adequate understanding of the distribution and abundance of marine turtle populations utilising Western Australian rookeries and marine habitats, the nature of inter-relationships between groups using different rookeries, and the linkages between nesting and living areas important for the maintenance of these adult turtle populations.
- Develop an understanding of the processes affecting the maintenance and abundance of these marine turtle populations as an aid to addressing management needs.
- Develop appropriate management measures and interpretation packages.

Summary of progress and main findings

- Paper on olive ridley turtles occurrence in Western Australia published in *Marine Turtle Newsletter*.
- Paper on Catch–Mark–Recapture (C–M–R) data for hawksbill turtles nesting on Varanus Island published in *Marine Biology*.
- Paper on historical time-series data from the Exmouth Gulf fisherfolk collaboration published in *Marine Turtle Newsletter*. This paper highlights the value of engaging industry and community participation in acquiring necessary field data and the difficulty also of building on that collaboration in seeking essential population demographic data for juvenile turtles.

- Technical solution to displaying tag and release location and recovery point connections for flipper tagged turtles developed with GIS Applications group.
- Review of database systems initiated. This is required to expedite further modelling collaborations that depend on efficient data management, extraction of information for the particular tasks involved, and the presentation of summaries and production of maps, graphs, and figures for publications.

Management implications

The provision of this further necessary knowledge will assist the development of appropriate conservation and management programs of marine turtle stocks in Western Australia to minimise the impacts of human activities on these animals.

Similar problems are anticipated to arise for necessary analysis of the other foundation adult female C–M–R population data sets.

Future directions (next 12 to 18 months)

- This project is being included as part of the broader review of turtle research and monitoring in DEC now in progress.
- Analysis of existing datasets will be undertaken on the loggerhead population on Dirk Hartog Island and on the hawksbill population on Rosemary Island.

Establishment of a long-term monitoring program for the proposed Dampier Archipelago Marine Park

SPP 2008-002

Team members

C Simpson, S Armstrong, K Bancroft

Context

The proposed Dampier Archipelago Marine Park (DAMP) is located off the north-west coast of Western Australia approximately 1650 km north of Perth. The area comprises of a wide range of marine habitats that support diverse marine biota, including more than 736 fish species and 230 scleractinian coral species, making the Dampier Archipelago the second most diverse site in Western Australia for hard corals. The marine environment of the area has considerable regional ecological and social conservation significance and is subject to increasing human use, including major offshore oil and gas production and associated port development. The region is also subject to a range of commercial and recreational fishing activities and the Dampier area has the highest per capita boat ownership in Western Australia.

Trends in resource condition over time are essential for assessment of the effectiveness of the proposed management regime for the DAMP. This project has established long-term monitoring sites, using a before-after control-impact (BACI) design, to obtain data on the abundance of selected finfish species and the cover of benthic reef communities ‗before' the zoning scheme is implemented. These data will provide estimates of the current condition of the reef and reef finfish populations at selected sites to compare with future data following the establishment of the DAMP and the implementation of the zoning scheme (i.e. comparisons between sanctuary and non-sanctuary zones). The data will also be compared to historical data to provide a longer-term temporal perspective.

Aims

Monitor targeted finfish abundance and length and rock lobster density such that any differences over time between protected and non-protected zones of the DAMPA can be detected.

Summary of progress and main findings

Two data reports have been completed.

Management implications

The project will provide information trends in resource condition over time for assessment of the effectiveness of the proposed management regime. It will increase understanding on the condition of Dampier Archipelago coral reef communities and the reef fish communities. It will increase public awareness of conservation value of the Dampier Archipelago.

Future directions (next 12 to 18 months)

This project has been moved under SSP 2012-015 WAMMP Sub-Project 3 'Fit to Park' and this SPP will be formally closed.

Spatial and temporal patterns in the structure of intertidal rocky platform communities of the Shoalwater Islands and Marmion Marine Parks

SPP 2009-002

Team members

A Kendrick, M Rule, J Huisman

Context

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

This study will determine relationships between the composition of these communities and the physical structure and location of the reefs.

Aims

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

Summary of progress and main findings

- Seven mainland intertidal reef sites were sampled in the MMP and SIMP by MSP and Swan Coastal District staff in the summer of 2011/12. This completed field sampling for this project, which has comprised both spatial (16 sites sampled in one year) and temporal (seven sites sampled in each of three years) components.
- Voucher specimen collections of algae and invertebrates have been created as a taxonomic aid. Over 100 species of algae and over 100 species of invertebrate have been identified so far with only a relatively small number of species remaining to be identified.
- A database has been compiled and analyses of these data has commenced. Progress to date indicates that differences exist between intertidal reef communities of the MMP and SIMP, and that exposure to wave action may be a significant factor that influences community structure.
- Compilation of a monitoring guide for intertidal reefs has commenced. This identification guide to common species will assist staff undertake future intertidal reef monitoring in these marine reserves.

- A *LANDSCOPE* article and an Information Sheet were published.

Management implications

- A baseline understanding of the intertidal reef condition in the MMP and SIMP in relation to natural processes will enable assessment of current and future anthropogenic impacts.
- This study will assist the implementation of long-term intertidal reef community monitoring across Western Australia's temperate marine parks and reserves.

Future directions (next 12 to 18 months)

- Additional sites at Garden Island and Carnac Island that could not be sampled during 2011/2012 due to adverse sea conditions will be sampled during the summer of 2012/2013 if conditions permit.
- The remaining species identifications and data analyses will be completed.

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

SPP 2009-003

Team members

S Wilson, T Holmes

Context

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

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

Aims

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

Summary of progress and main findings

- A paper on the diet of fish found along the north-west coast of Australia was published in *Environmental Biology of Fish*. The paper used published information to asses the diet of species targeted by fishers and explored how removal of these species may influence local trophic relations.
- A paper identifying habitat associations of juvenile fish was published in *PLoS ONE*. The study demonstrated corals of high structural complexity are important habitat for approximately half

the species investigated. The study also showed algal meadows are important juvenile habitat for some species, including species targeted by fishers.

- A paper assessing extinction vulnerability of fish was published in *Ecology Letters*. This paper assessed life history characteristics and habitat associations to compare susceptibility of coral reef fish to climate change and fishing, concluding that most fish are vulnerable to only one of these stressors.
- A manuscript that identified predators of juvenile fish using remote video cameras has been accepted in the journal *Coral Reefs*. The study demonstrated that small wrasse are an important predator of juvenile fish.
- A manuscript examining processes that influence coral recovery following large scale disturbances has been submitted to the journal *Conservation Biology*. This study suggested expanding macroalgae inhibits recovery and that marine protected areas may promote recovery.
- A manuscript examining the synergistic and relative effects of habitat degradation and fishing on reef fish communities at Ningaloo has been submitted to *Marine Environmental Research*. This study demonstrates habitat complexity and structure was an important driver of fish community composition.
- A *LANDSCOPE* article and Information Sheet have been produced.
- Satellite imagery and algal samples have been collected from the Ningaloo lagoon during winter, spring and summer to assess seasonal and spatial differences in macroalgal meadows. This information has been analysed and is being prepared as a manuscript.

Management implications

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

Future directions (next 12 to 18 months)

- Prepare a manuscript for submission on dietary assessment of fish species that are meso-predators.
- Prepare and publish data on algal communities.
- Assess the impact of 2011 coral bleaching on fish recruitment.

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

SPP 2009-013

Team members

A Kendrick, M Rule

Context

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

Aims

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

Summary of progress and main findings

- Seasonal invertebrate sampling was completed with Frankland District staff in July 2011, October 2011, February 2012 and April 2012, and invertebrate specimens were sorted from all samples in the laboratory.
- A database is being compiled and a voucher specimen collection is being built to identify species. Species identifications are being made with the assistance of external experts.
- A second survey of large bivalves inhabiting shallow sand flats of the WNIMP was completed with staff and students from Edith Cowan University as part of an ECU/DEC undergraduate teaching collaboration.
- A paper for publication titled: *'Bivalves inhabiting shallow sand flats of a temperate estuary*' is currently in preparation.
- A *LANDSCOPE* article and two Information Sheets have been written.

Management implications

- Determining the baseline condition of the WNIMP benthic invertebrate community in relation to natural processes will enable assessment of existing or future anthropogenic impacts.
- This study will assist the implementation of long-term benthic invertebrate community monitoring by DEC's Marine Monitoring Unit and regional staff in the WNIMP.

Future directions (next 12 to 18 months)

- Field sampling, laboratory processing and database compilation will be completed.
- Another Edith Cowan University – DEC collaborative bivalve survey in 2013 will provide three years of data.
- Data analyses will be completed and publications prepared.

Survey of the distribution and abundance of New Zealand fur seals in Western Australia

SPP 2010-007

Team members

K Friedman, R Campbell, D Holley, S Comer, P Collins, J Pridham, D Lierich, J Edwards

Context

Pinnipeds are a key higher order predator in Western Australia's temperate marine ecosystems. They are predominantly found in continental shelf environments of the higher latitudes but also inhabit temperate and equatorial regions. Historically, all species of pinniped were commercially harvested for their pelts and oil during the 18–20th centuries, resulting in large-scale reductions of population size and range. Some species have made recent recoveries, such as the New Zealand fur seal (NZFS; *Arctocephalus forsteri*), whereas other species, such as the Australian sea lion (ASL; *Neophoca* cinerea), remain vulnerable to extinction. The two resident species of pinniped in Western Australia are listed as specially protected under the *Wildlife Conservation Act 1950*. In contrast to ASLs, NZFSs appear to be undergoing a range and population expansion within Western Australia, having doubled their population size between 1989 and 1999. The range expansion appears to be continuing with haul-out colonies established along the south-west coast, but the rate of population growth and current abundance is unknown.

Aims

- Determine the current geographical range and population abundance of NZFS in Western Australia and compare these data with surveys undertaken in 1989 and 1999.
- Determine the spatial variation in growth rates and density-dependent growth rates of NZFS colonies.
- Design a more cost-effective survey regime that yields spatially relevant signals of change in NZFS populations at relevant time scales for conservation and management.
- Predict the likely rates of population increase and range expansion for the design of future management programs and population survey.
- Determine the breeding activity and schedule of sympatric ASL colonies.

Summary of progress and main findings

A draft manuscript and data report have been prepared on the survey of breeding sites of NZFS that documented an increase in abundance, and three new breeding colonies.

Management implications

The development and implementation of a long-term monitoring program that is both cost-effective and logistically feasible will also allow evaluation of the natural and anthropogenic factors, including climate change, that influence the abundance and distribution of these species. These data are important in helping to understand the ecological effects of an expanding higher-order predator population. Trends in abundance and preliminary dietary information on the NZFS also suggests that there may be some competition with the threatened ASL. This information will also allow better understanding of current and future trends in interactions with commercial fishing operations and the general public, and to manage this interaction more effectively.

Future directions (next 12 to 18 months)

This project is now complete with on-going pinniped monitoring activity being directed under SPP 2012-008 (Western Australian Marine Monitoring Program).

Effects of the Gorgon Project dredging program on the marine biodiversity of the Montebellos/Barrow Islands Marine Protected Areas

SPP 2010-008

Team members

S Field, J Moore, R Evans, K Friedman, J Huisman, G Shedrawi

Context

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

The GP includes a dredging program that will involve the removal and dumping of approximately 7.6M 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 Montebellos/Barrow Islands Marine Protected Areas (MBIMPA). This monitoring will also help inform future environmental impact assessments (EIA) by improving predictions of the spatial scale and nature of the likely impacts of dredging and dumping activities on sensitive marine communities. 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 re-suspension of spoil.
- Assess the effects of potential confounding natural (e.g. cyclones, disease, predation, bleaching) and other anthropogenic (e.g. fishing) pressures on the condition of coral communities of the MBIMPA.
- Assess the nature and extent of the impacts from the Gorgon dredging program on the social assets of the MBIMPA.

Summary of progress and main findings

- The program for monitoring the health of coral and fish communities, as well as the key pressures on these communities was continued throughout the remainder of the dredging operations and for six months following the completion of dredging in November 2011.
- An additional survey in September 2011 provided qualitative information of the health of coral communities, in addition to quantified water reflectance to improve the algorithm used for the automation of plume dispersal mapping, using readings of total suspended solids from satellite imagery.
- A November 2011 survey quantified the coral communities at the completion of the 18 month dredging operation, while the December 2011 survey quantified the distribution of coral diseases in the MBIMPA at the completion of the dredging operations. Surveys in February and May 2012 have quantified coral, fish, macroalgal communities and selected macroinvertebrate taxa up to six months following the completion of the dredging operations.
- Monitoring of the pressure field associated with the dredging has been continued for the remainder of the Gorgon dredging operations and for six months following the completion of dredging operations.
- Monitoring of other potential natural and anthropogenic pressures on the coral and fish communities have been continued, to quantify any additional impacts to these communities through to six months post-dredging operations.

Management implications

- The program provides a baseline for assessing potential impacts and recovery of coral communities within the MBIMPA, with a particular focus on potential impacts related to the dredging program for the Gorgon Project. It also provides information that will assist DEC to protect and manage 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.

Future directions (next 12 to 18 months)

- Completion of the final project report and scientific publications.
- Dissemination of results as appropriate through publications, reports and presentations to industry, other DEC staff and government departments and the scientific community.

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

SPP 2010-010

Team members

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

Context

In shallow, coastal waters, the condition of fish communities has traditionally been monitored, using a technique known as Underwater Visual Census (UVC). More recently, a technique for assessing finfish community condition has been developed that utilises stereo-video to capture imagery of fish

communities that is later analysed in the laboratory. Known as Diver-Operated Video (DOV), this technique has potential advantages over UVC because sampling theoretically requires less scientific expertise, takes less time in the field, and data analysts have access to reference material to help identify fish. In addition, it provides a permanent record of the survey that can be checked or revisited at a later point if required. However, DOV datasets may be more costly to process and it is unclear if video imagery captures the same level of diversity and abundance as skilled divers conducting UVC.

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

Aims

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

Summary of progress and main findings

- Field work at the Rowley Shoals, Ningaloo and Jurien Marine Parks as well as Rottnest Island have been completed and the data analysed. A draft manuscript is being prepared.
- Results from the Rowley Shoals were presented at the Australian Coral Reef Symposium.

Management implications

- Information obtained from this study will enable appropriate comparisons between historical datasets on fish communities that have been collected using both UVC and DOV methodologies.
- Evaluation of each methodology, including cost and time analysis, will provide advice to monitoring programs on which methodologies are most appropriate.

Future directions (next 12 to 18 months)

Prepare and submit a manuscript to an international journal.

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

SPP 2011-003

Team members

M Rule, A Kendrick, J Huisman

Context

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

The mangrove communities of SBMP are the most southern, extensive mangroves on the Western Australian mainland and are recognised as a significant marine park conservation asset, and eastern

Shark Bay is listed under the *Directory of Important Wetlands in Australia*. Mangroves in the SBMP display a wide variety of morphologies that are possibly related to the unique oceanographic characteristics of Shark Bay. While mangroves are a key ecological value of the SBMP, the current knowledge of these habitats is inadequate and impedes effective management in the reserve, and the broader World Heritage Area. For example, no significant areas of mangrove habitat currently exist within SBMP sanctuary zones. This project will provide the first comprehensive description of the variation among dense *Avicennia marina* stands in SBMP.

Aims

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

Summary of progress and main findings

- Fieldwork was completed and all data analysed.
- A paper on morphological variation in mangrove stands is in preparation.
- A paper on the algal community associated with mangrove pneumatophores in the SBMP is in preparation.
- An Information Sheet was produced.

Management implications

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

Future directions (next 12 to 18 months)

Publication of two peer-reviewed papers.

Regional-scale coral bleaching on Western Australian reefs

SPP 2011-008

Team members

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

Context

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

Aims

- Determine the dynamics of water temperature fluctuations during the warming event at local to regional scales.
- Quantify the spatial and temporal extent of coral bleaching across Western Australian coral communities.
- Investigate the post-impact response of reef corals to bleaching at local to regional scales.

- Inform future management strategies detailing responses to disturbance events, including refining of temperature thresholds for bleaching in Western Australian coral reef Marine Protected Areas.

Summary of progress and main findings

- Papers have been submitted for publication in *PLoS ONE* and *Coral Reefs.*
- An Information Sheet was written and two posters presented at conferences.

Management implications

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

Future directions (next 12 to 18 months)

- Knowledge transfer to Exmouth and Karratha regional offices and the community.
- Finalise publications.

WAMSI 1 Node 3: Science administration, coordination and integration

CF 2011-116

Team members

C Simpson, K Waples

Context

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

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

Aims

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

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

Summary of progress and main findings

- The Node 3 Final Summary Report was completed and submitted to WAMSI.
- Metadata for all WAMSI Node 3 projects provided to WAMSI Data Management Officer and available on Metadata Entry and Search Tool.
- Final reports have been submitted and approved by WAMSI for all but two of the research projects within Node 3.
- Joint communication activities have been coordinated with the Ningaloo Collaboration Cluster and AIMS.
- A report outlining the Western Australian State Government marine research priorities was developed and provided to the WAMSI Strategic Programs Committee for inclusion in the WAMSI Marine Research Institutes proposal to Government for WAMSI 2.

Management implications

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

Future directions (next 12 to 18 months)

- Ensure the findings and information from the Ningaloo research are disseminated to all relevant DEC users.
- Progress knowledge transfer to ensure research findings are available and useful to relevant managers.
- Submit a paper for publication in a peer-reviewed journal on the knowledge transfer framework and process.

WAMSI 2: Kimberley Marine Research Program

CF 2011-117

Team members

C Simpson, K Waples

Context

In June 2011, the Western Australian Government released the Kimberley Science and Conservation Strategy (KSCS), with its overarching aim to recognize and conserve one of the world's last great wilderness areas. The Kimberley Marine Research Program (KMRP) will undertake a program of marine research to support the management of the proposed state marine parks at Camden Sound, North Kimberley, Roebuck Bay and Eighty Mile Beach and the coastal waters outside these proposed marine parks. The KMRP will be developed and implemented through the Western Australian Marine Science Institution (WAMSI), with DEC as lead agency responsible for the direction, coordination and administration of the research program.

A research plan for the KMRP is being developed to address priority research and information needs to support the management of ecological and social values in the Kimberley region. The plan will comprise a suite of research projects focussed around two themes:

- bio-physical and social characterisation that aims 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
- understanding key ecosystem processes that aims to provide the scientific understanding of ecosystem functioning and response to a range of potential human impacts that are likely to arise in the future, including climate change.

Aims

- Ensure the KMRP research projects are developed in line with state prioirty needs, and will meet DEC management strategies for the newly-formed and proposed Marine Protected areas in the Kimberley.
- Ensure integration of research projects within the KMRP both in terms of field logistics and science findings.
- Ensure the outputs of the research undertaken through the KMRP reach targe taudiences.
- Ensure that knowledge transfer and uptake occurs between scientists, resource managers and decision-makers.

Summary of progress and main findings

- Publication of the Kimberley Marine Research Program Strategy outlining the general directions and process to develop the KMRP.
- Publication of the Kimberley Marine Research Program Science Plan outlining the key research areas and management questions that will be addressed.
- Development and review of 25 Science Concept Plans to be considered as part of the KMRP with advice provided to WAMSI.

Management implications

Research will increase capacity to manage human impacts on the Kimberley Marine Parks and improve understanding of the ecological significance of the biodiversity assets of the Kimberley.

Future directions (next 12 to 18 months)

- Development of the full suite of Science Project Plans that will comprise the KRMP.
- Initiation of early start research projects in the Kimberley.
- Communication activities to promote the KMRP science plan and suite of research to relevant marine resource managers as well as to local and Indigenous communities in the Kimberley.

North West Shelf Flatback Turtle Conservation Program Strategic Plan

CF 2011-118

Team members

S Whiting, H Raudino, K Crane

Context

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

Aims

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

Summary of progress and main findings

- A review of historical information relevant to marine turtle conservation in Western Australia is in progress.
- A review of international, national and state policy, legislation and other administrative arrangements relevant to marine turtle conservation in Western Australia is in progress.
- Drafts of *Conservation Plan for Marine Turtles in Western Australia* and *Strategic Plan for the NWSFTCP* have been completed.
- A pilot study to track hatchling sea turtles using acoustic array technology with transmitter tags was undertaken in collaboration with the University of Western Australia and the Australian Institute of Marine Science. The results showed the suitability of this technology with no adverse impact on the welfare of the hatchlings.

Management implications

The key purpose of this plan for the NWSFTCP is to establish a robust program of works within a strategic long-term framework. This offset fund provides an opportunity to fill key gaps in knowledge, establish long-term robust monitoring programs and deliver management outcomes.

Future directions (next 12 to 18 months)

- *Conservation Plan for Marine Turtles in Western Australia* finalised and published.
- *Strategic Plan for the NWSFTCP* finalised and published.
- The NWSFTCP Advisory Committee and Panel of Experts are approved and operating.
- The NWSFTCP is integrated with new initiatives (e.g. Kimberley Node of WAMSI 2 and NGO programs).

Development of a strategic marine research plan for the Western Australian Department of Environment and Conservation: 2010–2015

CF 2011-122

Team members

S Wilson, A Kendrick, C Simpson

Context

Historically, much of the research needed to inform DEC's marine conservation and management programs has been delivered through externally-funded programs such as the Northwest Shelf Joint Environmental Management Study, the Strategic Research Fund for the Marine Environment and Western Australian Marine Science Institute. Although a small research capacity has recently been established within DEC Marine Science Program, external delivery of research will remain a key mechanism to meet DEC's marine research needs for the foreseeable future.

A strategic marine research plan is being developed to ensure that DEC marine research needs are identified, prioritised and delivered in a timely manner so that appropriate scientific information is available to support DEC's marine protected areas, marine fauna management and marine environmental protection programs. The document will outline a systematic framework to identify and prioritise DEC's marine research needs, the opportunities and constraints to meeting these needs and the strategies needed to take advantage of the opportunities and overcome the constraints.

Aims

Develop and progressively implement a strategic marine research plan to support Western Australia's marine protected areas, marine fauna management and marine environmental protection programs.

Summary of progress and main findings

- A paper on research and monitoring priorities in marine protected areas has been submitted to the *Journal of Environmental Management*. The study collates research priorities identified by managers and scientists around Australia and examines their perceptions of research requirements.
- A paper on the baseline water quality at Jurien Bay Marine Park is in press at *Conservation Science Western Australia*.

Management implications

Development and implementation of the strategic marine research plan will enhance DEC's capacity to identify, prioritise and deliver DEC's marine research needs for departmental marine conservation and management programs.

Future directions (next 12 to 18 months)

Progressive implementation of the strategic marine research plan.

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

SPP 2012-007

Team members

K Friedman, C Nutt

Context

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

Aims

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

Summary of progress and main findings

- A Technical Reference Group (TRG) consisting of representatives from key stakeholder groups was established in May 2012 and terms of reference drafted to support the functioning of this group.
- A web-based collaborative project space and online communications tool were developed and implemented in May 2012 to facilitate input and cooperation from TRG participants.
- Information housed within DEC, Western Australian Museum and Australian Institute of Marine Science, and publicly accessible information held by industry, have been reviewed and prioritised for use in the construction of historical time-series datasets.

Management implications

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

Future directions (next 12 to 18 months)

- Obtain data from the relevant custodians, construct historical time-series datasets, report recommendations, and make metadata accessible to key stakeholders and the broader public.
- Transfer of knowledge and key findings to stakeholders and the broader public.

The Western Australian Marine Monitoring Program (WAMMP)

SPP 2012-008

Team members

K Friedman

Context

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

Aims

Develop and implement a long-term, state-wide marine protected area and threatened marine fauna monitoring program in Western Australia.

Summary of progress and main findings

- A draft strategic plan to guide WAMMP has been developed and is currently being finalised.
- A draft manuscript describing the framework and process components has been written.
- A series of guideline documents for the selection of condition, pressure and response indicators, and the delivery of MER in MPAs and across the state has been written.
- A draft manuscript describing the operational framework to support the annual Marine Parks and Reserves Authority review process has been written.
- Time-series condition, pressure and (management) response information metrics collected through WAMMP were used by managers to help design MPA work programs and to fulfil statutory auditing requirements.

Management implications

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

Future directions (next 12 to 18 months)

- Finalise and publish the WAMMP strategic plan.
- Publish a manuscript describing the framework and process components of WAMMP.

- Publish a series of guideline documents for the selection of condition, pressure and response indicators, and the delivery of MER in MPAs and across the state.
- Continue to increase monitoring, evaluation and reporting focus of social values, anthropogenic pressures and stakeholder participation.

WAMMP Sub-project 1: Asset knowledge review and standard operating protocol documentation

SPP 2012-013

Team members

K Friedman, C Simpson, A Kendrick, S Wilson, K Bancroft, K Onton, T Holmes, M Rule, K Waples

Context

Monitoring the status of environmental assets assists DEC to fulfil its statutory responsibilities for the conservation of the State's biodiversity, as it is recognised that the 'health' of the environment is a powerful surrogate for biodiversity conservation. Long-term, systematic, integrated marine monitoring, together with evaluation and reporting of change, is a key management strategy for measuring success of Marine Protected Area (MPA) and marine fauna management plans, as early detection of detrimental impacts facilitates responsive and active adaptive management for the conservation of marine biodiversity. Use of a Condition–Pressure–Response monitoring framework will assist managers in assessing management efficiency and effectiveness, which is a critical element of an adaptive management framework.

Aims

Develop a process to guide the writing of Asset Knowledge Reviews that identify what condition, pressure and management response indicators need to be measured, and the methods to implement the monitoring of these indicators with due consideration of scientific 'power', cost, relevant historical data and practicality.

Summary of progress and main findings

- A draft manuscript, that provides guidance on developing WAMMP Asset Knowledge Reviews, has been developed for publication in the scientific literature.
- A comprehensive review of available literature and historical information has been undertaken to provide an improved understanding of the spatial patterns of natural, anthropogenic and climate change pressures on key marine biodiversity assets in Western Australia, to assist the development of specific asset knowledge reviews.
- Draft manuscripts of the Asset Knowledge Reviews for fish, seagrass, mangrove, little penguins, coastal biological communities and water quality have been prepared for publication.
- A draft manuscript describing an information management system for long-term institutional marine biodiversity monitoring programs has been prepared for publication.

Management implications

Monitoring, evaluation and reporting programs are a key element in the adaptive management cycle and are aimed at continuously improving the efficiency and effectiveness of DEC's conservation and management programs. Using the most representative and effective indicators assists WAMMP in delivering multi-decadal data sets to inform adaptive conservation management initiatives.

Future directions (next 12 to 18 months)

- Publish Asset Knowledge Reviews for key marine biodiversity assets.
- Complete draft Asset Knowledge Reviews for dugong, sea-lions, seabirds and stromatolites.
- Refine Standard Operating Procedures as field procedures are trialled and protocols are standardised.

WAMMP Sub-project 2: Historical time-series development

SPP 2012-014

Team members

K Friedman, K Bancroft, C Simpson

Context

Extensive monitoring of the marine environment of Western Australia has been undertaken over the last three decades or more, and although many of these monitoring programs were often-issue specific and constrained in time and space, these data have significant potential to help understand historical trends in the condition of biodiversity assets, the pressures on these assets and, in some cases, the management responses to these pressures. This project will examine historical datasets from marine research and monitoring programs in Western Australia that are relevant to the objectives of WAMMP. While the main aim is to reconstruct historical trends in asset condition and pressures to extend our understanding ‗backwards in time', this project will also inform the process of selecting indicators and methods and temporal and spatial scales of WAMMP monitoring programs into the future.

Aims

- Develop a framework outlining the decision rules to guide the construction of historical time-series on asset condition, pressure and management response for high priority biodiversity assets identified in Marine Protected Area (MPA) management plans and threatened species recovery plans.
- Incorporate datasets into MPA annual asset performance reports to assist managers in their management role, and more fully populate their asset report cards that are part of the Marine Parks and Reserves Authority audit process (see WAMMP sub-project 4).

Summary of progress and main findings

- A manuscript that provides guidance for the development of historical time-series has been prepared.
- A historical time-series has been completed for coral community data from Ningaloo Marine Park and a publication of a statewide metadata analysis of coral condition is currently well-progressed .
- Historical time-series development is underway for: finfish and coastal communities in Ningaloo Marine Park, mangrove communities in various MPAs and various anthropogenic pressures (e.g. boat ownership) across the State.
- Historical sea surface temperature has been collated to provide a 30 year historical time series for each marine protected area (data sharing with NOAA).

Management implications

The construction of historical time-series will capture past investment in marine research and monitoring and assist the design and data delivery within WAMMP monitoring programs. Knowledge of historical trends in marine biodiversity asset condition, pressure and management response will also facilitate an improved understanding of future trends by providing a context of change over time and variation among years. This will facilitate better understanding and improve the efficiency and effectiveness of DEC marine conservation and management initiatives.

Future directions (next 12 to 18 months)

- Finalise and publish the historical time-series development guideline manuscript.
- Continue to identify, retrieve and assess historical records of asset Condition-Pressure-Response data to create standardised historical time-series of relevance to WAMMP.

WAMMP Sub-project 3: 'Fit to park'

SPP 2012-015

Team members

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

Context

This project is focussed on implementation of monitoring programs in the field using the indicators and methods identified in WAMMP Sub-project 1, with due acknowledgement of historical data identified in WAMMP Sub-project 2. The initial focus of this project will be to determine the appropriate spatial and temporal scales for monitoring. WAMMP needs to ensure that monitoring locations and monitoring timing and frequency allows biodiversity asset monitoring data to be comparable within and between major geographical areas of interest and to operate within the context of adaptive management.

Aims

- Develop guidelines for determining the spatial and temporal scales of asset Condition–Pressure–Response (CPR) monitoring programs.
- Identify the practical constraints to the implementation of WAMMP monitoring programs within geographical areas of interest.
- Progressively implement asset CPR monitoring programs for asset priorities outlined in management plans within a structured but adaptive delivery framework.
- Progressively implement asset CPR monitoring programs for threatened marine fauna according to established DEC priorities within a structured but adaptive delivery framework.

Summary of progress and main findings

- Finfish monitoring completed at Marmion, Shoalwater, Ningaloo, Montebello/Barrow Islands and Rowley Shoals marine parks.
- Coral communities monitored in Ningaloo, Montebello/Barrow Islands and Rowley Shoals MPA's. In addition, a coral community recovery assessment was completed at Coral Bay, Ningaloo Marine Park.
- Seagrass monitoring was undertaken at Shark Bay, Jurien, Marmion and Shoalwater Islands MPAs under both historical and new sampling regimes. Macroalgae monitoring was initiated at Metropolitan and Jurien marine parks.
- Mangrove monitoring was completed at Ningaloo Marine Park and significant progress was made in capturing and processing remote imagery of mangrove in all MPAs where it is listed as an asset.
- Invertebrate monitoring of settlement of rock lobster juveniles was continued in Ningaloo Marine Park. Turtle monitoring was undertaken in the Shark Bay, Ningaloo and the proposed Dampier Archipelago MPAs. A little penguin population survey and survey of breeding status was completed in the Shoalwater Islands MPA.
- Water and sediment quality monitoring was undertaken at Ningaloo Marine Park, while water temperature monitoring arrays were established and maintained in all marine parks.

Management implications

The CPR data being collected with regard to biodiversity, physical and social assets will be available for marine park coordinators and regional staff to help them assess the efficiency and effectiveness of DEC's management. The data will also be incorporated into internal DEC and Marine Parks and Reserves Authority audit processes of MPAs.

Future directions (next 12 to 18 months)

- Produce a guideline for determining the spatial and temporal scales of asset CPR monitoring, and submit for publication in a peer-reviewed journal.

- Progressively implement and document CPR monitoring programs for threatened marine fauna according to established priorities.
- Focus on integration of monitoring across assets, to improve the effectiveness and efficiency of field data collection, data post-processing and system reporting.

WAMMP Sub-project 4: MPRA/DEC audit support and management effectiveness reporting

SPP 2012-016

Team members

K Friedman, K Bancroft, C Simpson

Context

One of the statutory roles of the Marine Parks and Reserves Authority (MPRA) is to monitor the implementation of Marine Protected Area (MPA) management plans. The audit function of the MPRA is expressed in three levels of review: as an annual performance review of the progressive implementation of MPA management plans; audit of management performance for each MPA on a periodic basis; and a ten-year audit of the implementation of the management plan.

A comprehensive MPA performance assessment report, including a Condition–Pressure–Response (CPR) report card, is presented to the MPRA annually. WAMMP assists DEC regional MPA staff and DEC specialist branches in this regard, by providing asset CPR monitoring data and advice for use in ‗populating' the MPRA's MPA performance assessment framework.

Aims

Assist MPA managers and DEC specialist branches in meeting DEC/MPRA audit requirements by advising on and, where appropriate, providing CPR data to ‗populate' the MPA performance assessment framework the MPRA use to service their audit function.

Summary of progress and main findings

- Annual Marine Protected Area 'Management Effectiveness Reporting' reports were compiled for each State MPA for 2010/2011.
- Work-flow process to provide asset CPR monitoring reports is being implemented. This work-flow has some initiation time costs but offers more standardised and user-friendly reporting in out-going years.

Management implications

The audit process provides asset CPR time-series information annually for all Western Australian MPAs and is a statutory requirement of DEC under the CALM Act. These data are used as part of an emerging adaptive management culture by regional MPA managers to improve the efficiency and effectiveness of their management programs.

Future directions (next 12 to 18 months)

- Finalise the process to meet DEC and MPRA audit reporting requirements.
- Produce a manuscript that describes input into the auditing of DEC biodiversity conservation initiatives and outputs, and submit for publication.
- Roll-out of a systematic and standard annual process for the provision of asset CPR monitoring updates for individual assets and MPA's.
- Compile asset CPR monitoring updates into Annual Marine Protected Area 'Management Effectiveness Reports' for each State MPA for 2011/2012.

WAMMP Sub-project 5: Community participation and liaison

SPP 2012-017

Team members

K Friedman, K Waples

Context

Stakeholder engagement and participation is recognised as a key strategy to develop better links between managers, scientists and the community at large. Government, industry and community partnerships within the context of WAMMP offer the opportunity of extending the scope of an early warning system for detecting change in the marine environment and opportunities to share information and improve understanding across many marine conservation issues and priorities that are of wider interest.

Aims

- Successfully engage with stakeholders and the general community on issues of marine conservation, with special regard to WAMMP activity.
- Provide opportunities for direct involvement in monitoring, related activities and presentations of information to ensure broad involvement of the community in managing the health of the marine and coastal environment.
- Ensure the data collected by a wide range of stakeholders will complement the monitoring data collected by DEC scientists and operational managers so that together these data will be used by both DEC managers and local communities to help manage human impacts on their local marine environment.

Summary of progress and main findings

- WAMMP presentations were made to three community and five DEC groups.
- Finfish monitoring, completed by DEC at the Montebello/Barrow Islands, Shark Bay, Ningaloo and the metropolitan marine parks was undertaken in collaboration with ‗Reef Life Survey', a community-based citizen science organisation.
- Coral monitoring completed in Ningaloo and Montebello/Barrow Islands MPA's with a greater involvement of commercial tour operators.
- Seabird monitoring completed by community participants at Shoalwater and Marmion marine parks.
- Volunteers were supported and trained in post-processing and reporting of coral, little penguin and seagrass monitoring information.

Management implications

The management of MPAs and threatened marine fauna will benefit from increased stakeholder understanding resulting from extensive communication of, and direct community participation in, WAMMP activity and reporting.

Future directions (next 12 to 18 months)

- Engage MER programs from other state and regional conservation agencies in sharing their strategic and annual information for the benefit of DEC, state and regional collaborators.
- Continue to support community NRM and other conservation initiatives that align with WAMMP objectives and foster industry, government agency, university, and public participation programs.

WAMMP Sub-project 6: Marine information management system

SPP 2012-018

Team members

S Whiting, K Friedman, F Mayer, C Severin

Context

The research and monitoring capacity within the Marine Science Program focuses effort on the ecological and social science needed to inform the adaptive management of Western Australia's marine protected area network, the conservation of threatened marine fauna and the conservation of the state's marine biodiversity generally. These programs will generate enormous volumes of data that must be analysed, presented and stored for future uses. To complete these tasks an information management framework is needed to support research and monitoring requirements. Information management in this context is the development and execution of architectures, policies, practices and procedures that properly manage the full data lifecycle needs of the Marine Science Program, with particular emphasis on the long-term datasets required for WAMMP.

Aims

- Establish and implement a best practice information management system for the Marine Science Program with a particular emphasis on the orderly management and presentation of long-term datasets produced by WAMMP.
- Provide a framework and process for orderly management and sharing of scientific literature, stock images and footage.

Summary of progress and main findings

- Guidelines for the Marine Science Program's data collection and information management are being aligned with data management recommendations of the Australian National Data Service and the Atlas of Living Australia.
- Two major components for data warehousing and meta-data cataloguing have been designed and are being implemented.
- A literature management system has been established.
- A bulk file storage system, with large capacity for handling of video files, has been established.
- Mobile data collection tools and protocols are being developed to WAMMP requirements.

Management implications

As the primary purpose of the monitoring and research is to acquire, evaluate and make available natural resource information to contribute to adaptive management, a well structured data handling and archive system is a critical component for management. Ordered, accessible and secure data derived from long-term monitoring studies and research projects offer managers an insight into work that has been completed. Having the raw data from past studies, limits the duplication of work and offers the opportunity for reassessment if new questions arise.

Future directions (next 12 to 18 months)

- Publish the three-year Marine Science Strategic Plan for Information Management.
- Provide a future-proof, standardised storage solution for long-term monitoring data sets.
- Provide a metadata catalogue to make data sets discoverable and accessible.
- Develop methods and work flows to enter and retrieve data from these solutions.

SCIENCE APPLICATIONS UNIT

UNIT MANAGER: PAUL GIOIA

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

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

SPP 2011-010

Team members

P Gioia, S Hopper (Royal Botanic Gardens, Kew)

Context

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

Aims

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

Summary of progress and main findings

- The underlying infrastructure and analysis environment has been completely replaced with high performance equipment and state-of-the-art software.
- The 2004 analysis (using 2002 data) has been repeated using the new environment and the results are being compared. This will enable differences in both sample effort and species richness patterns to be evaluated over a ten-year period.

Management implications

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

Future directions (next 12 to 18 months)

- Complete the re-analysis, including sampled richness and endemism.
- Apply null-model techniques to validate patterns under randomisation.
- Repeat the bio-regionalisation analysis and compare with original 2004 regionalisation to see if regions are sustained with the addition of ten years of data.
- Produce two manuscripts for review.

Online GIS biodiversity mapping (NatureMap)

CF 2011-106

Team members

P Gioia

Context

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

Aims

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

Summary of progress and main findings

- A major release of NatureMap was made available in February 2012. This release included four new data sources, ten new or updated reference layers and a host of enhancements. In particular, attention was paid to presenting the most accurate and high quality information as the default, rather than all available records. Changes were made in response to user feedback, particularly from those in industry and conservation planning backgrounds.
- Substantial progress was made towards a new Great Western Woodlands theme.
- NatureMap recorded 315 new registrations, bringing the total to 1178, a 27% increase.

Management implications

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

Future directions (next 12 to 18 months)

- The underlying infrastructure of NatureMap will be reviewed and upgraded in line with industry standards.
- New reference layers and species datasets will be added as they become available.
- An substantial update to the Banded Iron Formation theme is scheduled for July 2012.
- An update to the Wheatbelt NRM theme is scheduled for August 2012.
- Specific bug fixes and urgent functionality requirements will be implemented.
- An evaluation will be made of the role of NatureMap within DEC in relation to the Atlas of Living Australia, with a view to clarifying future investment in both initiatives.

Provision of authoritative names of Western Australian taxa

CF 2011-108

Team members

P Gioia

Context

DEC, academia and the community rely on authoritative species names to manage species databases. Without authoritative names, the ability to provide and integrate information is substantially impeded. WACensus, a database system, is the primary mechanism for managing those names. WACensus

captures both current names and synonymies and information is disseminated widely throughout Western Australia. DEC assumes a leadership role in providing authoritative names to assist in bio-inventory of both plants and animals, and the delivery of high quality information to a range of clients. There is a need to provide a standard mechanism for collection and management of plant species information. Max is a species database management system that substantially improves data accuracy through facilitating the correct use of names, and promotes a standard database design integrated with WAHerb, the Western Australian Herbarium's specimen database.

Aims

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

Summary of progress and main findings

- WACensus has been maintained, with minor bugs fixed and enhancements implemented as required.
- A number of bugs were resolved in Max and two new releases made available in February and June.

Management implications

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

Future directions (next 12 to 18 months)

- Fungi names are scheduled to be implemented within the 2012–2013 financial year.
- Further embed WACensus information into DEC's information systems.
- Complete the new fauna collecting book forms.
- Evaluate the future use of, and investment in, Max within the context of new data collection tools developed as part of the Atlas of Living Australia.

OBSERVATORY

PROGRAM LEADER: RALPH MARTIN

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

Variable star observations

SPP 1998-009

Team members

R Martin, A Verveer, A Williams, G Lowe

Context

This project represents a long-term worldwide collaboration to study variable stars.

Aims

Monitor the brightness of variable stars to provide increased knowledge of the structure of stars and the processes associated with stars.

Summary of progress and main findings

Tested the Perth Lowell Automated Telescope at Perth Observatory and the Zadko Telescope at Gingin to determine their suitablitiy to detect extrasolar planets transiting the disk of their host star. The initial test was satisfactory.

Management implications

This research will be in collaboration with the HAT-South Survey for transiting exoplanets that is a program based at the Australian National University and the University of Western Australia.

Future directions (next 12 to 18 months)

- Begin monitoring exoplanet candidates.
- Develop methods to analysis exoplanet data.

Imaging and CCD photometry of transient and variable sources

SPP 1998-011

Team members

A Williams, R Martin, A Verveer, G Lowe

Context

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

The Murchison Widefield Array (MWA) is a low frequency (80–300MHz) radio telescope being built at the proposed ‗Square Kilometre Array‘ site in Western Australia. When operating, the MWA will generate a complete, high-resolution image of the entire sky, horizon to horizon, every eight seconds, in the selected radio frequencies. The MWA is one of three official 'precursor' telescopes for the Square Kilometre Array radio telescope (the other two are ASKAP in Western Australia, and 'MeerKAT'

in South Africa), and the only one operating at low frequencies. It is expected to find vast numbers of transient sources at these frequencies, including types of object that have never been seen before. Development of software and electronics for the MWA is being undertaken through the International Centre for Radio Astronomy Research (ICRAR).

Aims

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

Summary of progress and main findings

- The prototype telescope (32 individual array elements or 'tiles') was dismantled early this year, and construction of the full 128-tile array is almost complete. All trenching, cabling, and other construction work is finished, and the steel mesh ground-planes for the tiles are in place.
- The MWA team has one refereed paper in press, describing the design strategy used to locate the individual tiles in the full array for maximum resolution given the geographic restrictions (trees, roads, cabling/trenching costs and requirements, etc). Three refereed MWA papers have been submitted.

Management implications

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

Future directions (next 12 to 18 months)

Continued involvement in development of the MWA and its role in the Square Kilometre Array.

Monitoring gravitational microlenses

SPP 1998-013

Team members

A Williams, R Martin, A Verveer

Context

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

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

Aims

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

Summary of progress and main findings

- Seven peer reviewed papers were published this year, including one in the journal *Nature*. The *Nature* paper summarised the results from six years of planet hunting using microlensing, with the groundbreaking discovery that planetary systems like our Solar System are extremely common, and low-mass planets like the Earth outnumber high-mass planets like Jupiter. In total, there are more planets than stars in the Milky Way.
- Another extrasolar planet approximately 10 times the mass of the Earth was discovered.

Management implications

Gravitational microlensing has developed into a powerful tool for studying stars and planets. The paper published this financial year in the journal Nature, by the PLANET group, contributes to the growing body of evidence that planets are common in our galaxy. This paper's findings are scientifically significant and possibly culturally significant.

Future directions (next 12 to 18 months)

Perth Observatory staff have left the 'PLANET' microlensing group and joined another collaboration (MiNDSTEp) led by researchers at St Andrews University in Scotland, to build on already existing ties between St Andrews and staff at the International Centre for Radio Astronomy Research (ICRAR).

Supernova search

SPP 1998-014

Team members

R Martin, A Verveer, A Williams, G Lowe

Context

This project involves a long-term study of supernovae—an endpoint in stellar evolution. The Perth Automated Supernova Search is a search for extra-galactic supernovae in low redshift spiral galaxies and uses the Perth Lowell Automated Telescope (PLAT) at Perth Observatory.

Aims

- Contribute to the broader study of supernovae by employing methodical search techniques to detect supernovae at early stages of their evolution.
- Make an independent determination of the supernovae rates within late spiral galaxies.
- Undertake additional research on the supernovae found by collecting photometric light curves of supernovae discovered by Perth Automated Supernova Search.

Summary of progress and main findings

- One supernova was discovered: SN2011ed in galaxy IC 4839. This is the 30th supernova discovered by the Perth Automated Supernova Search.
- The automated supernova search now runs as a background program: that is objects in the supernova search are scheduled for observation only when no other observing program requires telescope time.
- Light curves for supernova sn2012aa were collected. This object is approximately six times fainter than any object observed on our telescope.

Management implications

Observations of anomalous supernovae facilitate the understanding of the mechanisms of supernova explosions and the supernovae‘s progenitor stars.

Future directions (next 12 to 18 months)

Increase the number of supernovae that are photometrically monitored.

Astronomical evaluation of sites in Western Australia

SPP 2000-006

Team members

R Martin, A Verveer, J Biggs (Curtin University)

Context

The evaluation of various sites regarding their suitability for astronomical observations are the key aspects of this project.

Aims

Test appropriate Western Australian sites regarding their suitability for astronomical observations.

Summary of progress and main findings

A peer-reviewed paper entitled "Measuring and mapping the night sky brightness of Perth, Western Australia" was published. A major finding of this study is the effect of land use and geography on night sky brightness that results from artificial lighting (light pollution). The relationship between these factors and the distance from Perth's CBD are quantified and interpreted from the sky brightness map.

Management implications

The study provides a baseline for future studies of Perth and a possible method for mapping the sky brightness of other cities and is believed to be the first map of the light pollution for an entire city ever published. This paper will be of use to urban planners and astronomers with an interest in modelling the effect of artificial lighting on a large scale.

Future directions (next 12 to 18 months)

This project is now complete and will be closed.

Astronomical information services

CF 2011-101

Team members

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

Context

This core function involves providing information of direct use to various groups within the community. Its authority is underpinned by active involvement in astronomical research. Some of the projects are long-term worldwide collaborations. There is a significant demand for astronomical information from many different groups and individuals within the community.

Aims

Provide relevant and timely astronomical information.

Summary of progress and main findings

- There were over 346,000 'page viewings' of the Observatory‘s website.
- The layout of the Observatory's website was refined and content rewritten.
- Volunteers have begun cataloguing historical items at the Observatory, including the book collection.

Activity measures

Activity	2011/2012	2010/2011	2009/2010	2008/2009
Telephone enquiries	5,358**	4,972	8,916	4,817**
Email enquiries	602	998	494	769
Consultations	12	0	9	38
Newspaper, radio & TV	132	116	109	129
www page views (000s)*	346*	260*	244*	323*
Positive responses to ‗quality' questions in surveys (%)	98	98	99	98
Satisfaction of information requests as they occur (%)	***	98	99	98

*From 2007/2008, 'page views' rather than raw 'hits' have been recorded as a performance indicator because this better reflects the actual use of a website.

**Affected by a long duration equipment malfunction.

***Sample size too small to calculate.

Management implications

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

Future directions (next 12 to 18 months)

- Make further progress towards a self-guided tour by writing fact sheets about the telescopes at the Perth Observatory.
- Complete the catalogue of historical items at the Observatory and make this information available on the web.
- Continue to catalogue the books in the Perth Observatory's library.
- Continue to improve the astronomical web services, including social media.

Astronomical outreach and education

CF 2011-102

Team members

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

Context

This core function involves providing services of direct use to the general public and education sector. Its authority is underpinned by active involvement in astronomical research. Some of the research projects are long-term worldwide collaborations. There is a significant demand for astronomy education services from many different groups and individuals within the community.

Aims

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

Summary of progress and main findings

- The Observatory supported charitable institutions by running an Astronomical Field Night for the Organ Donation and Tissue Foundation.

- The number of visitors attending star viewing nights and day time guided tours totaled 4,174 for the year.
- Twenty lectures and presentations were made to university undergraduates, primary school students and community groups.
- Customer satisfaction surveys showed 98% of customers were satisfied with their visit or the service provided by the Observatory, and 98% were satisfied with the educational quality of the services in which they participated.
- The Observatory purchased a used dome (from the University of Western Australia) for 76-cm aperture public telescope.
- The astronomy component of the primary school curriculum was integrated into the Observatory's guided day tour.
- Began training volunteers to take day tours.

Activity Measures

Activity	2011/2012	2010/2011	2009/2010	2008/2009
Star viewing sessions	76	72	77	102
Night visitors	3,348	3,461	3,604	4,334
Sunday guided tours	0	11	46	37
Daytime guided tours	826	356	689	1,131
Astronomy field nights	1	1	7	10
Field night attendance	3,500	3,000	1,488	1,846
Lectures and talks	20	21	21	44
Talk attendance	893	350	825	1,294
Student consultations	0	0	2	25
Customer satisfaction (star viewing and guided tours, %)	98	98	97	98
Astronomy awareness raised (%)	99	97	100	100
Educational quality (%)	98	98	99	98

Management implications

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

Future directions (next 12 to 18 months)

- Recruit and train additional volunteers to take day guided tours.
- Assemble the dome for the 76cm telescope.
- Evaluate ways of using the two internet telescopes to better support astronomy education in Western Australia.

STUDENT PROJECTS

The following reports were supplied.

Scientist: **I Abbott**

Student: P Van Heurck

Project title

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

Progress report

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

Fieldwork was completed in spring 2010. To date, 1,100 samples containing 23,100 invertebrates have been sorted. 445 beetle morphospecies have been identified, of which 220 are rare and possible short-range endemics. To date, 97 of these morphospecies were only collected from the patchy mosaic fire regime and 64 morphospecies only collected from the wildfire regime. A prodromus listing each species' fire niche and life history attributes is being prepared.

Scientist: **D Algar**

Student: K Koch

Project title

Genetic diversity and phylogeography of Australian cats

Progress report

This project aims to determine the genetic diversity and phylogeographic structure in wild cats. Samples from various islands and locations on the mainland were genetically analysed using mitochondrial DNA and nuclear DNA. Preliminary results have given an insight into the origin and population structure of feral cat populations on Christmas Island, Cocos Keeling Island, Dirk Hartog Island and various locations throughout Western Australia. Sampling is ongoing on Dirk Hartog Island to be able to provide recommendations for management and biosecurity. Further analyses will include feral cats from Asia in order to determine possible introductions from Asia onto the Islands.

Scientist: **D Algar**

Student: N Dybing

Project title

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

Progress report

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

Only one cat from Christmas Island harboured an ectoparasite. Fifty-four intestines have been searched and 94% of these harboured parasites. No ectoparasites were present in cats from Dirk Hartog. Six intestines were searched and all of these harboured parasites. Only 10 of the Dirk Hartog cats had stomachs available for analysis, with 50% having ingested plant material and 40% having ingested invertebrates. Birds, reptiles and rodents were ingested by 30%, 30% and 20% of cats respectively. Cats were collected from 11 locations in south-west Western Australia. Of these, 56% harboured ectoparasites. Twenty-nine GI tracts have been searched and 59% harboured helminth parasites. Rodents were ingested by 76% of the south-west cats—species of rodents need to be further identified but include house mice and rats. Plant material, invertebrates and birds were ingested by 66%, 28% and 17% of cats respectively. Cats were also found to have eaten reptiles (14%) which include skinks, lizards and frogs (3%).

Scientist: **D Algar**

Student: Low Bing Wen

Project title

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

Progress report

Understanding the spatial ecology of the invasive black rat (*Rattus rattus*) is necessary to inform management actions. This study investigates densities and home range size of black rats around seabird colonies and urban areas on Christmas Island, where rat predation is suspected to be adversely affecting fledgling success among local seabirds. It was hypothesised that rat densities would be higher and home range sizes smaller in urban areas owing to more consistent food availability. Rat densities in seabird colonies, which averaged 24.6 rats per hectare, were higher than that of urban areas, which averaged 10.9 rats per hectare. Additionally, both the core and foraging home ranges of male black rats were significantly larger compared with their female counterparts, with male rats maintaining larger home ranges in urban areas compared with seabird colonies. Conversely, female black rats had smaller home ranges in urban areas compared with seabird colonies. Our findings suggest a possible correlation between food availability, rat abundance and home range size. Additionally, the spatial distribution of breeding females across the landscape had a significant influence on the home ranges of male rats. These findings have significant implications for proposed efforts to manage rat populations on Christmas Island.

Scientist: **D Algar**

Student: G Hayes

Project title

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

Progress report

Christmas Island is home to unique and diverse fauna, which may be threatened by populations of introduced feral cats (*Felis catus*) and black rats (*Rattus rattus*). A four-year eradication program to remove these introduced species from the island commenced in 2010. As part of the eradication program, this study examined the diet of feral cats and black rats to determine the direct predatory impact on native species. It was hypothesised that feral cats would primarily consume black rats and native vertebrate species, while black rats would supplement their diet of plant species with native vertebrate and invertebrate species. Additionally, a bait trial was conducted to determine the bait preference of black rats on the island. It was hypothesised that a coconut additive would improve the palatability of Racumin bait.

The gut contents of feral cats and black rats, euthanised as part of the eradication program, were analysed. At the same time, a bait trial was conducted using three forms of Racumin bait. Examination of the guts of 33 feral cats showed the most frequently occurring food items were plants (72.7%) and invertebrates (63.6%), and the most abundant were plants (13.7 ± 3.5%), birds (12.4 ± 4.3%) and invertebrates (11.1 ± 2.9%). In the guts of 51 black rats examined, plant material was the most frequently occurring (58.8%) and abundant (20.8 ± 7.8%) food item. Paste soaked in coconut milk was identified as the most palatable bait form.

Scientist: **D Algar**

Student: M Johnston

Project title

Development of Curiosity feral cat bait

Progress report

This PhD has only recently commenced and will document the trials undertaken to develop and evaluate the Curiosity cat bait. This bait medium contains a ‗Hard Shell Delivery Vehicle' (HSDV) that encapsulates the toxin para-aminopropiophenone to trigger toxicoses in cats. The HSDV increases the specificity of the bait medium by exploiting differences in the mechanical digestion of food by some vertebrates. Many potential non-target species are known to reject large inert particles in their diet; however the cat is more likely to ingest such particles by virtue of its characteristic form of mastication which selects large portions of food for swallowing, without grinding and sorting of small inert particulates.

Scientist: **D Algar**

Student: A Coddou

Project title

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

Progress report

This project will examine the effectiveness of baiting for introduced rats on Christmas Island using the bait type and bait station spacing defined by previous studies conducted on the island. Trials to evaluate baiting effectiveness have commenced.

Scientist: **A Burbidge**

Student: N Grubb

Project title

Informing better translocation programs—territory size as an indicator of habitat suitability for the noisy scrub-bird (*Atrichornis clamosus)*

Progress report

The aim of this project was to investigate the habitat preferences of the noisy scrub-bird using territory size as an indicator of habitat suitability. As part of the project, noisy scrub-birds were translocated from Bald Island to the Angove reserve, near Two Peoples Bay. Habitat features investigated included vegetation structural attributes and predator activity levels. Outcomes of the project will be useful in evaluating success of future translocations.

Scientist: **M Byrne**

Student: J Moniodis

Project title

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

Progress report

Sandalwood oil is one of the world's most valuable essential oils. Western Australian sandalwood, *Santalum spicatum*, is one of seven commercially valuable sandalwood species well known for its pleasant fragrance and importance to many Asian cultures. *S. spicatum* is currently harvested from natural stands and, due to past exploitation combined with slow regeneration and habitat loss, there is concern over the sustainable management of this species. Plantation production alleviates pressure from natural populations and ensures a sustainable supply of sandalwood in the future. Mature heartwood of *S. spicatum* contains a diverse array of cyclic and acyclic terpenoid skeletons, including bergamotene, farnesene, santalenes and the highly sought after fragrance ingredients, the santalols. Oil production is not consistent with either heartwood yield or composition, so the current research attempts to better understand this variation by investigating the natural genetic and chemical diversity, genes involved in oil biosynthesis, and the different environments in which *S. spicatum* grows in Western Australia.

Several P450 candidates have been selected from an EST and 454 libraries derived from *S. album* wood tissue. Two of these candidates belonging to the CYP76 group are currently being tested in a yeast system that has successfully produced the santalol precursors *in vivo*. A 454 library is currently being constructed to enable further characterisation of genes from *S. spicatum* to advance plantation development through improved selection and to reduce strains on natural populations. A chemotaxonomic investigation of approximately 200 individuals distributed throughout the wheatbelt (predominantly), goldfields, Shark Bay and Carnarvon has been completed to identify specific chemotypes. Results suggest chemical diversity within and between regions, with some individuals exhibiting high santalol and low farnesol content, an undesirable constituent. For these individuals, genetic analyses using microsatellite data are being applied to aid understanding of the genetic structure of this species and the relationship to heartwood oil content. Environmental data, including host species and distances, tree height, diameter, soil type and pH, and rainfall have been collected from the field to carry out statistical analysis to identify any significant relationships between oil yield and composition, genetics and these various environmental factors. Statistical results thus far have identified santalol and farnesol as two key components driving the variability in heartwood chemistry, which is important for future breeders who wish to select trees with high santalol content and conversely low farnesol content. Results of the studies will be applied to the future conservation of *S. spicatum*, improvement of plantation management with the potential of metabolic engineering of desirable oil constituents *in vitro.*

Scientist: **M Byrne, P Poot**

Student: E Dalmaris

Project title

Wandoo decline: ecophysiological and genetic variation among provenances

Progress report

Eucalyptus wandoo Blakely is an endemic species of the south-west of Western Australia and one of the main tree species of the wheatbelt region. From the late 1970s it has been under threat from the phenomenon of ‗wandoo crown decline'. This project is investigating the complex ecophysiology of wandoo and its environment as well as its phylogeographical patterns.

Environmental stress factors, drought and salinity were investigated in *E. wandoo* through glasshouse experiments. Responses of seedlings to the stresses did not show any significant differences between the populations and no association with either rainfall or aridity index (the ratio of rainfall to evapotranspiration), thus suggesting that there is limited evidence for adaptation of *E. wandoo* to drought and salinity, at least at the seedling stage, between populations that originate from geographically far apart and ecologically quite distinct locations.

The phylogeographical study of the species, based on the analysis of cpDNA, identified a geographically structured pattern of diversity, with the presence of two clades that followed a climatic gradient from the mesic to the semi-arid region. The basal lineage occurs in populations of the western, coastal margins of the distribution. The second lineage is comprised of the more eastern populations that occur in the semi-arid region. Estimation of lineage separation is 530,000 years ago, placing it in the mid to late Pleistocene. Diversity of haplotypes in the central wheatbelt area suggests presence of a refugial area, with expansion of haplotypes into drier areas to the north and east. More recent expansion of wandoo into drier areas may be an explanation for less tolerance to climatic changes. A paper has been prepared for submission to *Journal of Biogeography*.

Scientist: **M Byrne**

Student: V Stylianou

Project title

Morphological and physiological traits of a widespread eucalypt species along a rainfall gradient in south-west Australia

Progress report

Morphological and physiological traits of the widespread oil mallee species, *Eucalyptus loxophleba* ssp. *lissophloia*, across a rainfall gradient in south-west Australia are being investigated. Phenotypic responses in traits such as plant height, leaf area, specific leaf area, leaf nitrogen and phosphorus concentrations, carbon and nitrogen isotopes and wood density, as well as the physiological processes of transpiration, stomatal conductance and photosynthesis, may enable them to tolerate water deficits as rainfall declines. This project examined these traits along a rainfall gradient in south-west Australia, with the expectation that stands at the drier end of the gradient may have higher adaptive capacity to respond to the increasingly dry climate predicted for Australia's south-west. Restoration efforts may then focus on sourcing genetic material from stands that have adaptations to water deficit, rather than focusing on sourcing propagules from local populations, thereby enhancing success of restoration efforts in a changing climate. The influence of genetics and the environment on traits relating to water use efficiency were examined by comparing the response of trees in the drier natural populations with those transplanted into a trial growing in wetter environments.

Results of this study showed that plasticity is important in influencing the expression of leaf morphological, physiological and chemical traits of *E. loxophleba* ssp. *lissophloia* growing across the climate gradients associated with the extensive geographic range of the species. In contrast to the

physiological traits, the leaf morphological traits showed evidence of adaptation since the variability in leaf traits, such as leaf length, leaf width, leaf dry mass, and leaf area, was retained when grown in the plantation. The study showed the adaptive capacity *E. loxophleba* ssp. *lissophloia* is high, with evidence of both genotypic and phenotypic responses, which would give this species the ability to withstand the large-scale climate changes that are predicted to take place in south-western Australia over the next century.

Scientist: **M Byrne, D Coates**

Student: H Nistelberger

Project title

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

Progress report

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

Collection of the three species, *Atelomastix bamfordi*, *Grevillea georgeana* and *Banksia arborea* is complete. Preliminary genetic results using selected chloroplast DNA markers indicate low genetic diversity and little genetic structuring in both plant species. Trials are underway to examine variation at nuclear loci. Results for *A. bamfordi* using selected mitochondrial DNA markers indicate genetic structuring across BIF ranges with a pattern indicative of an historical vicariance event leading to isolation of BIF populations during the mid-Pleistocene around one million years before present. Both mitochondrial and nuclear genetic markers show higher genetic diversity in the large, more topographically complex BIFs and this has significant conservation implications for the future management of the species.

Scientist: **M Byrne, M Millar**

Student: M Zhou

Project title

Phylogeography of *E. leucophloia*: comprehension of evolutionary processes in the Pilbara Region and implications for mining and conservation

Progress report

This project aimed to investigate phylogeographic structure and identify historical events and geographic features that may have affected the current genealogy and distribution in *Eucalyptus leucophloia,* a dominant species in the Pilbara. Phylogeographic analysis of DNA was undertaken, and high haplotype diversity was found in the Hammersley and Chichester Ranges, with low diversity in surrounding lowland areas. The results support a hypothesis that the Hammersley and Chichester Ranges may have been refugia in the arid Pilbara region during the changing climate conditions in the Pleistocene. This information can be implemented in environmental protection plans to preserve the genetic diversity present in refugial areas.

Scientist: **S Field**

Student: J Turner

Project title

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

Progress report

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

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

Scientist: **K Friedman, K Bancroft**

Student: E Do Khac

Project title

Asset management study on coastal biological communities of Ningaloo Marine Park

Progress report

The aim of this study was to undertake a review on the management of coastal biological communities and to develop a historical time series on the condition of coastal biological communities in the Ningaloo Marine Park. The data has contributed to the development of a remote sensing technique for monitoring the condition of coastal biological communities and the production of a draft asset knowledge review.

Scientist: **T Friend**

Student: J Austen

Project title

Characterisation of a novel Western Australian *Trypanosoma* species isolated from native marsupials

Progress report

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

Scientist: **T Friend**

Student: J Pridham

Project title

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

Progress report

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

Sites have been selected from two areas where all four species occur: Mt Gardner (Two Peoples Bay Nature Reserve) where potoroos naturally occur and the Norman's Beach enclosure (Waychinicup National Park) where potoroos were translocated in 2010; and a Water Corporation reserve joining Two Peoples Bay Nature Reserve where bush rat, quokka and quenda occur. Samples have been obtained from all sites with continuing trapping to occur in 2012 to obtain further scats for analysis.

Scientist: **A Kendrick**

Student: F Vitelli

Project title

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

Progress report

The broad aim of this study is to determine the trophic role of pomacentrid fishes as herbivores on temperate algal-dominated reefs, with a particular focus on the abundant species *Parma mccullochi*. To achieve this, the study will determine the diet of this species, including ontogenetic changes, and the impact of grazing by pomacentrids on algal production and the composition of temperate reef algal communities. Fieldwork has commenced in the Marmion and Shoalwater Islands Marine Parks.

Scientist: **A Kendrick, S Wilson**

Student: A Turco

Project title

The role of *Kyphosus* spp. in reef ecosystems

Progress report

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

A pilot study to assess a variety of different field survey techniques has been completed. Field studies will be carried out in the Marmion, Shoalwater Islands and Ningaloo marine parks.

Scientist: **L McCaw**

Student: M Peace

Project title

Fire weather

Progress report

Weather is a primary driver of bushfire behaviour. Much of the science linking interactions between fire weather and fire behaviour was established in the 1960s and 1970s, but new advances in understanding and computer modelling capability provide the scope to better understand the interactions of weather and fire behaviour. Coupled fire atmosphere models have the ability to capture feedback loops between the fire and the atmosphere, enabling better understanding of how a fire may modify the environment in which it is burning. This is of particular importance during large-scale, high intensity bushfires.

This project aims to explore the capabilities and applications of the Weather Research and Forecasting (WRF) model by examining case studies of actual bushfires, and by running idealised simulations where the sensitivity response to different input variables can be tested. Case studies will include examples of forest and shrubland fires in southern Australia.

Progress has been made in running the WRF model using fuel and weather parameters for the Kangaroo Island bushfires of December 2007. A detailed technical report examining significant aspects of the behaviour of these fires has been published. A case study of unexpectedly severe fire behaviour during a prescribed burn in October 2010 at Layman block east of Margaret River has been accepted for publication in the *Australian Meteorological and Oceanographic Journal*. Factors identified as contributing to fire behaviour included low level sea breeze convergence, potential atmospheric instability, entrainment of dry air from aloft, and vertical circulation associated with a frontal change.

Scientist: **M Millar**

Student: A Williams

Project title

Are banded ironstone formations refugia for two Western Australian *Acacia* species?

Progress report

Climatic fluctuations have had a significant influence on species distribution and evolution. There is a need for more phylogeographical studies in the southern hemisphere, particularly in the arid and semi-arid zones of Australia where, unlike much of Europe and North America, aridity, and not glaciation, has been the dominant force shaping distributional changes in species during the Pleistocene. Banded iron formation (BIF) ranges in the Midwest Region of Western Australia have been put forward as possible refugia for arid and semi-arid zone species. This study examined the phylogeography of two *Acacia* species, *Acacia karina* and *A. cockertoniana*, in order to identify evolutionary divergence within species and test the hypothesis of BIF ranges as refugia. Variation in chloroplast haplotypes among populations revealed implications for conservation management activities, but phylogeographic patterns did not provide strong support for BIF being historical refugia for these two species.

Scientist: **K Morris**

Student: J Dunlop

Project title

Factors affecting fauna translocation success

Progress report

Vertebrate fauna translocations, particularly to mainland sites, have a low rate of success (<30%). One potentially contributing factor that has been poorly studied is the impact of parasite loads and pathogenic disease in founder individuals during the stressful establishment period. Each individual carries many species of ectoparasite, enteric parasites and haemoparasites that may impact directly or indirectly on the host or other species in the environment of the establishing population. For example, blood parasites in the *Trypanosoma* group have been closely associated with the decline of the woylie, *Bettongia penicillata*. This work aims to assess the survivorship impacts of disease and parasite load within the establishing population of golden bandicoots (*Isoodon auratus*) and boodies (*Bettongia lesueur*) during the first 18 months of translocation. We experimentally manipulated the population by regularly dosing half the animals with a broad spectrum antiparasitic treatment in order to disrupt the life cycles of a variety of ecto, enteric and haemoparasites. During this intensive monitoring, other demographic and life history data was collected, as well as biological samples such as blood, DNA and fecal samples.

Progress to date includes longitudinal trapping and data collection following the release of 160 golden bandicoots from Barrow Island and 170 boodies from Dryandra and Barrow Island. Approximately 800 blood samples were collected for species-specific detection of *Trypanosoma copemani* and an unnamed new trypanosome. Presence of these trypanosomes will be added to models of survivorship to determine if there is a relationship, as well as to follow the pattern of infection across the population. Ectoparasites and enteric parasites present in faecal samples are being identified to species level to determine whether there has been a change in species diversity in the new environment.

Scientist: **K Morris**

Student: R Thavornkanlapachai

Project title

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

Progress report

This project aims to investigate genetic mixing of translocated populations established from multiple source populations. The mixing produces various outcomes depending on the genetic distance between the breeders. These outcomes can largely impact on the success of a translocated population. To investigate the mixing impacts, translocated populations established from multiple populations with different genetic distinction are needed. A recent translocation of boodies (*Bettongia lesueur*) at Lorna Glen (DEC) provides a good opportunity to explore this question. The translocated populations of dibblers (*Parantechinus apicalis*) on Escape Island (Perth Zoo) and black-flanked rock wallabies (*Petrogale lateralis lateralis*) at Paruna Sanctuary (Australian Wildlife Conservancy; AWC) are also included in this study. The populations used to establish these translocations are different at a subspecies level, genetically distinct level, and closely related species level.

To determine whether two source populations mate randomly, 10–18 microsatellite markers and mitochondrial DNA from each species will be used to assign each offspring to its parents and to identify its ancestral population. Body measurements, body condition, sex and number of pouch young will be compared between the populations to see overall differences, as well as between offspring and their parents to see whether the mixing has any influence on the fitness of the offspring. The majority of the samples from all three species (boodies, dibblers and black-flanked rock wallabies), have now been obtained from DEC, Perth Zoo and AWC. All relevant approvals have been also obtained. DNA extractions of all available boodie tissue samples are completed. Optimisation of boodie amplification reactions have been accomplished. The majority of available samples have been sent for microsatellite fragment analysis and mtDNA sequencing. The results are in the process of being analysed.

Scientist: **P Poot**

Student: C Allen

Project title

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

Progress report

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

Currently a glasshouse experiment has been set up to compare the drought tolerance of seedlings of two threatened *Acacia* species (*A. unguicula*, *A. awestoniana*) with that of several provenances of two widespread *Acacia* species (*A. saligna*, *A. acuminata*). The provenances of the widespread species have been selected on the basis of a proxy for local water availability (i.e. site aridity index). This experiment will generate insights into the mechanisms of drought tolerance amongst *Acacia* species, the level of differentiation in drought tolerance within species, and the likelihood of threatened species being able to persist under future warmer and drier conditions.

Scientist: **M Stukely**

Student: A Rea

Project title

Classical and molecular taxonomy and pathogenicity testing of *Phytophthora* species

Progress report

The aim of this project was to characterise, from a molecular taxonomic perspective, undescribed *Phytophthora* taxa occurring in natural ecosystems in Western Australia, to formally describe three of these new species, and to assess the pathogenicity of these three species.

This project is now complete and two publications have arisen from this work: one describing *Phytophthora elongata*, a novel pathogen from the jarrah forest; and one describing *P. arenaria* and *P. constricta,* two novel and potentially endemic species of *Phytophthora* associated with episodic dieback of kwongan vegetation.

Additional DNA sequencing (four nuclear and two mitochondrial loci) has been performed on isolates of *P. multivora* and other clade 2 *Phytophthora* isolates. Two manuscripts are currently in preparation. The first of these is a coalescent analysis of *P. multivora,* a pathogen widespread in the south-west of Western Australia and postulated to be endemic. Data strongly indicates that this species originates in the Republic of South Africa. The second manuscript explores the phylogenetic relationship between closely related isolates residing in *Phytophthora* clade 2a, focussing on the northern hemisphere species *P. plurivora*, and presents evidence of two previously undescribed taxa (one from Hainan, China, the other from the Royal Botanic Gardens in Surrey, UK) as well as the first isolation of *P. plurivora* in Australia (NSW).

Scientist: **M Stukely**

Student: A Simamora

Project title

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

Progress report

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

Scientist: **S van Leeuwen**

Student: J Harvey

Project title

Regional variability in salmon gum communities in the Great Western Woodlands

Progress report

This project aims to determine if there is regional variation in the understorey of *Eucalyptus salmonophloia* woodlands across the Great Western Woodlands (GWW) and, if so, what is driving it. It will then integrate relevant existing survey data from across the Wheatbelt to assess the variation across the two bioregions. Using this site based data and selected GIS layers, the project will attempt to model the distribution of woodlands dominated by *E. salmonophloia* in Western Australia.

This project fills large gaps in the floristic surveys of the GWW, which have focused on the banded ironstone and greenstone ranges. Nearly 50 sites have been selected in old growth woodlands or woodlands where the known timber cutting and or grazing history has been estimated. A further 50 sites will be sampled in spring 2012. Data is being collected on species composition, cover and height, tree dimensions, site-based variables and soil physical and chemical characteristics. Survey work is being assisted by members of the Wildflower Society of Western Australia survey team. Methods developed for modelling vegetation distribution will contribute to protocols for mapping vegetation across the GWW and the state.

Scientist: **A Wayne**

Student: Y Abdad

Project title

An epidemiological and serological study of *Rickettsia* in Western Australia

Progress report

The aim of the project was to investigate *Rickettsiae* in Western Australia. The prevalence of *Rickettsia gravesii* in four tick species collected from humans and wildlife in south-west Western Australia was <15% in *Amblyomma albolimbatum*, 75% in *A. triguttatum*, 51% in *Ixodes australiensis* and 25% in *I. fecialis*. *Rickettsiae* prevalence in feral pigs in Perth water catchment areas was 49%. Rickettsial prevalence in humans was related to occupational and recreational activities, showing that the risk of infection of people was greatest with higher exposure to activities in the bush and wildlife. Prevalence was 45% in Barrow Island workers, 50% in Whiteman park staff, 23% for recreational rogainers and 2% in the control group (Murdoch University staff and students). No official reports of spotted fever in humans have been reported in Western Australia but increased awareness of the potential for such cases is warranted.

Scientist: **A Wayne**

Student: K Bain

Project title

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

Progress report

This project aims to determine: i) if a reliable estimate of quokka abundance can be obtained from indicators of activity including scats, tracks and runnels; ii) identify the preferred habitat of quokkas in southern forests; iii) identify the current distribution and abundance of quokkas in the southern forests (Warren region) and the influence of fire; iv) determine the mobility and activity patterns of quokkas in the broader landscape; and v) in collaboration with others determine whether the sub-populations constitute a functional meta-population.

Between November 2010 and March 2011, stepwise logistic regression models of habitat surveyed for presence/absence of quokka identified the density of the near-surface fuel layer, vegetation structure and proximity to a different fuel age as the subset of variables that best predict the probability of occupancy of quokka.

Forest areas with fire treatment and comparable control sites have been examined for quokka abundance and habitat quality pre- and post-fire to determine the effect of fire on habitat use and the time taken for habitat to become re-colonised post-fire.

To determine movement patterns and habitat use, radio collars fitted to 17 animals in a recently burnt Jarrah forest ecosystem have been monitored since autumn 2011. Associated monitoring by cage and camera trapping indicate that feral cats are responsible for almost complete recruitment failure by predating young immediately after pouch emergence. In January 2012, 10 additional collars were deployed on quokkas within a longer-unburnt site to provide an indication of the effect of vegetation age on movement patterns.

DNA has been provided to staff at Murdoch University, who will be assisting with DNA processing.

Scientist: **A Wayne**

Student: H Burmej

Project title

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

Progress report

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

Scientist: **A Wayne**

Student: G Kaewmongkol

Project title

Characterisation of two novel *Bartonella* species isolated in ticks and fleas from woylies (*Bettongia penicillata*)

Progress report

Bartonella species are recognised increasingly as pathogens of humans and dogs. As more *Bartonella* species are being identified from many different countries and animals, their pathogenic potential is also being re-evaluated. The aim of this project is to investigate the presence of *Bartonella* species in ticks and fleas collected from woylies and other mammals in the south-west of Western Australia. Nested-PCRs of the citrate synthase gene (gltA) and intergenic spacer (ITS) region were used for the detection method. The genetic characterisation of *Bartonella* species was established by the multilocus sequences analysis. A novel species was detected from fleas (*Pygipsylla hilli*) and ticks (*Ixodes australianisis*) collected from woylies. Multilocus sequence analysis of the 16S rRNA, gltA, ftsZ and rpoB genes and ITS revealed that this isolate is a distinct species and related to *Bartonella australis* previously isolated from kangaroos in the eastern states. Another species was detected from ticks collected from woylies. Phylogenetic analysis of the citrate synthase gene demonstrated that this isolate is also a potentially novel *Bartonella* species. Further study is required to extend the investigation of these two novel species in more ectoparasites collected from woylies and, if possible, in their blood or tissue samples. It is not known whether these organisms have the potential to cause disease in woylies; however, the proposed research may enable some questions to be answered. Four papers have been published from this research.

Scientist: **A Wayne**

Student: S Pan

Project title

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

Progress report

The project work has been focusing on genotyping of *Toxoplasma gondii* in Western Australian wildlife species. Significant effort has been made to collect a wide range of samples, including frozen carcasses and fresh samples. In total, 417 samples (335 marsupials and 82 introduced animals) and 177 individuals (137 marsupials and 40 introduced animals) were screened for *T. gondii*. Nested-PCR markers specific for gene locus B1, SAG1, SAG2, SAG3, SAG4 and GRA6 have been carried out for all samples. Extensive optimisations were carried out to select the right gene markers suitable for Western Australian wild animal samples and reproducible results were obtained. This study has accumulated over 330 DNA sequences across multiple animal species and gene markers.

In total, 60% (249 out of 417) tissue samples and 75% (133 out of 177) individual animals were infected with *T. gondii* based on the analysis of two loci (B1 and SAG3). The marsupial samples were detected with typical infection rate of 75% (103 out of 137). Out of the total 30 Western Australian native mammals species studied, 24 were infected with *T. gondii* (80%). High variation and unique *T. gondii* genotypes in multiple loci have been revealed in a range of animal species such as kangaroos, chuditch and woylie. This research has been presented at three international conferences and a paper is currently in review for publication in an international journal.

Scientist: **A Wayne**

Student: A Worth

Project title

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

Progress report

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

Scientist: **A Wayne**

Student: G Yeatman

Project title

Wildlife ecology in the southern jarrah forest

Progress report

This project will investigate ecological attributes of woylie and other small mammals in the jarrah forest. Specifically it aims to: i) complete a baseline survey of the small terrestrial vertebrates in Perup Nature Reserve; ii) investigate patterns of distribution and abundance of small vertebrates in the southern jarrah forest in relation to habitat; iii) calculate an estimate of woylie (*Bettongia penicillata*) home range size in and outside the newly constructed Perup Sanctuary; iv) investigate spatial patterns in the current distribution of woylies across the Upper Warren Region in relation to habitat variables; and v) investigate temporal patterns in the distribution of woylies across the Upper Warren Region over the past three decades.

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

Scientist: **A Wayne**

Student: K Zosky

Project title

Food resources and woylie declines in south-west Western Australia

Progress report

The aim of the project is to examine the dietary ecology of the woylie and investigate its role in current population declines. Specific aims are to examine temporal and spatial variation in the diet of the woylie, examine changes in woylie diet in relation to population decline, and investigate food resource availability.

The study involves two components, an assessment of diet using faecal material collected during woylie population monitoring and seasonal fungi surveys to assess food resource availability. Fifty-six species of hypogeal fungi have been identified (three new). Fungi constitute the dominant dietary component throughout south-western Australian populations but the diet also includes plant, invertebrates and seed. There is limited spatial variation in diet at regional and subregional scales but strong seasonal changes, with fungi being greatest in winter. A strong relationship exists between fungi availability and diet composition. The study concludes that the dietary ecology of the woylie is not a primary causative agent of the recent declines in woylie populations. A paper has been published from this work in *Australian Mammalogy*.

Scientist: **S Whiting**

Student: X Hoenner

Project title

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

Progress report

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

This project has produced major outcomes by extending our understanding of hawksbill turtle biology and ecology in the areas of nesting biology, identification and description of critical habitats during the inter-nesting, post-nesting and foraging phases of life history, and understanding migration and diving behavior. This information will be formalised in four scientific papers and has been communicated back to the local community via several types of media. In addition, this project developed a cooperative working relationship with the Anindilykwa Aboriginal Land Council at Groote Eylandt and developed a community census program for ongoing monitoring

---

Scientist: **S Whiting**

Student: J Tedeschi

Project title

Assessing the resilience of marine turtle embryos to extreme temperatures

Progress report

This project aims to determine if gene expression in temperature-sensitive genes varies within/between turtle species. A major objective is to determine if the differential expression of specific genetic markers can be used as proxies for estimating the tolerance of marine turtle embryos to extreme temperatures. More specifically, this project will investigate whether there is phenotypic variation with and between species and at what pace thermal tolerance may evolve.

Scientist: **S Wilson**

Student: E Ashworth

Project title

Quantitative diet analysis of four mesopredators from Ningaloo Reef, Western Australia

Progress report

The functioning of fish assemblages rests mainly on the trophic status of species. Gut content analyses provide insight into feeding behaviours and lead to better understanding of the complex interactions between fish species. Mesopredators are common on coral reefs and fluctuations in their abundance may influence prevalence of prey; however, there is a lack of information on mesopredator diets, making it difficult to assess how changes in their abundance will influence prey, reef trophodynamics and ecology.

This study examined the gut content of four mesopredator species: *Epinephelus rivulatus*, *Parapercis clathrata*, *Pseudochromis fuscus* and *Synodus dermatogenys*. Mobile benthic invertebrates, particularly decapods, were the main item in the diet of three mesopredator species. However, one species, *S. dermatogenys*, fed exclusively on other fish species.

Scientist: **S Wilson**

Student: J Goetze

Project title

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

Progress report

The overall aim of this study is to determine whether periodically fished areas (tabu) can successfully protect locally targeted reef fish assemblages and how the intensity of harvest events impacts on their effectiveness. To do this, a large-scale empirical study will focus on testing variation in the intensity that tabu areas are harvested. Using the results from this study and others in the region, a meta-analysis will be done that will examine whether tabu areas are a successful fisheries management tool that can provide a viable alternative to permanent marine reserves by either maintaining or increasing local fish stocks. This information will assist with the formation of a set of guidelines that provide advice to local communities on how to manage these tabu areas.

Scientist: **S Wilson, J Moore**

Student: E Josephitis

Project title

Comparison of three digital image analysis techniques for assessment of coral reef bleaching

Progress report

Digital imagery techniques for quantifying the benthos are increasingly used to monitor the health of coral reefs. There are many techniques to assess coral habitats from images, but there is no clear answer as to which one is most effective. The aim of this study was to compare the effectiveness and relative cost (processing time) of three image analysis techniques commonly used to assess coral/benthic cover and coral bleaching. Digital photographs, taken 1m above the substrate at 1m intervals along 16 transects (50 images per transect), were used to examine the extent of coral cover and bleaching within coral communities of the Montebello and Barrow Islands in February 2011 following a temperature anomaly event. Each image was evaluated by: i) assessing habitat under six randomly placed points (point count); ii) dividing images into 20 square blocks and recording the dominant item in each block (block); and iii) visually estimating benthic cover and bleaching without reference to points or grids (visual). Overall there was a high degree of congruence between the commonly used techniques and there were no significant differences when comparing coral cover or the extent of bleaching. Similarly, there was no detectable difference in the precision of coral and

bleaching estimates made using the three techniques; however, analyses carried out using the ‗Point count' and ‗Visual' techniques were quicker and therefore more efficient than the ‗Block' technique. The findings of this study demonstrate that techniques commonly used to assess coral cover and bleaching from digital images are compatible and that they may be combined to provide greater spatial and temporal assessment of coral reef condition.

Scientist: **C Yates**

Student: A Cochrane

Project title

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

Progress report

Germination and early seedling establishment are high risk phases in the life cycle of obligate seeding plant species. This research aims to assess the extent of south-west Western Australia *Banksia* vulnerability to a changing climate in these phases and to determine the potential for phenotypic plasticity in seed and seedling traits across populations of four *Banksia* species along a rainfall gradient. Investigations of temperature profiles for seed germination in populations of the four *Banksia* species sampled from across an east-west climate gradient (24 populations) were completed. A large common-garden experiment investigating the effects of increased temperature and altered rainfall on seedling emergence, early growth and survival in populations of the four *Banksia* species was completed. An advanced draft of a manuscript reviewing the evidence for population variation in seed germination and seedling traits across climate gradients was prepared. In the coming year the project will undertake a glasshouse irrigation/warming trial and a laboratory moisture stress experiment and begin analysis and write-up of completed experiments.

Scientist: **C Yates**

Student: A Williams

Project title

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

Progress report

Experimental studies investigating the relationship between climate and plant demography are needed to develop better models for understanding the vulnerability of species to climate change. This research aims to quantify plant demographic behaviour (survivorship, growth and fecundity) under projected climate change using experiments that manipulate rainfall and temperature. The research is being undertaken in the diverse kwongan heath vegetation on the Eneabba Sandplain, a nationally recognised biodiversity hotspot, which is projected to become warmer and drier. Rainfall manipulations using rainout shelters (rain decrease) and irrigation (rain increase), and temperature manipulations using open top chambers (temperature increase) began in winter 2010. Four sites were chosen covering different fire treatments and topographies: burnt dune, burnt swale, unburnt dune and unburnt swale.

Preliminary results for the mature (unburnt) vegetation sites show that increased rainfall improved growth, health and reproduction, while both reduced rainfall and increased temperature had negative impacts. The increased temperature treatment had the largest effect on plant performance, and this may be a consequence of the warmer temperatures influencing plant growth and reproduction directly and indirectly through increased evapotranspiration and reduced soil moisture, respectively. In the post-fire regenerating sites, only growth and health were measured as plants had not yet recovered to a reproductive state post-fire. The rainfall and temperature manipulations had little effect on the growth

of resprouting species. One-year seedling trials using sewn seed were set up in winter 2011 to assess the response of seedlings to rainfall and temperature manipulations. Germination was higher in the swale than the dune, with the rainfall and temperature treatments having little effect. Survival was negatively affected by increased temperature and reduced rainfall, with the increased rainfall treatment showing no consistent differences from the control. Surviving seedlings were harvested and will be weighed for above- and below- ground biomass.