Department of Environment and Conservation

Science Division annual research activity report

and management implications

2010 – 2011

Department of
Environment and Conservation

DIRECTOR'S MESSAGE

Scientific research is a key responsibility of the Department of Environment and Conservation. The efficiency and effectiveness of DEC's policy, planning, management and regulatory frameworks is dependent largely upon the scientific evidence that informs these processes. As such, DEC invests significant resources in the conduct of science on key and priority areas. Scrutiny of the science behind DEC policies and programs will inevitably increase as the development of the state continues and economic interests are affected by these policies and programs.

While science is carried out across the breadth of the agency, the work of Science Division represents the department's core investment in the scientific research required to underpin its policy and operations. This document reports on the research activities undertaken in the Science Division in 2010/2011 and is an essential component of the accountability of research and communication of knowledge to stakeholders both within the department and in the wider scientific community. It supplements the major forms of communication that we use to transfer knowledge to target audiences, such as journal publications, technical articles, community articles, workshops, talks, and conference presentations.

Some of the research we do is carried out solely by DEC scientists but the majority is carried out in collaboration with both internal and external partners to leverage DEC's investment in science most effectively. It is pleasing to see that we have maintained and grown collaborations with our partners in the past year.

We are engaged in many adaptive management projects carried out in partnership with Nature Conservation, Sustainable Forest Management and regional staff throughout the state. Our engagement in the Gorgon Project has involved a major project in translocations of animals from Barrow Island, and we are contributing to the delivery of programs in the Kimberley Science and Conservation Strategy and the Great Western Woodlands Initiative. In addition to major programs, most of our research involves active interaction between individual scientists and regional staff. Key projects include rangelands restoration at Lorna Glen, fire mosaics at Walpole Wilderness, management of dieback infestations in the Fitzgerald River National Park, recovery of Gilbert's potoroo, investigation of factors influencing decline of woylies, and recovery and management of threatened flora.

Our collaborations with external partners have been consolidated and expanded with significant research activity with many universities, CSIRO, industry and corporate institutions.

We held a strategic workshop with key staff from CSIRO to evaluate current collaborations in the context of a portfolio of research activity, and to identify synergies in research activity and explore new research opportunities and science questions that inform biodiversity conservation. We have engaged with CSIRO in two innovative genomics projects relating to invertebrate and soil biodiversity under the umbrella of the CSIRO Science and Industry Endowment Fund.

We continue to be actively involved in several Cooperative Research Centres and have a significant involvement in other large scale endeavors, such as Western Australian Marine Science Institute (WAMSI 2) and Terrestrial Environmental Research Network (TERN), that will deliver integrated scientific research in both the marine and terrestrial spheres. We have active partnerships with many universities both in Western Australia and throughout Australia, through a variety of means including as industry partners in Australian Research Council (ARC) Linkage projects. We currently support 64 Honours, Masters and PhD students, giving them direct exposure to research aimed at achieving management outcomes.

We value our engagement with industry and the corporate sector, particularly support from Rio Tinto, BHP Billiton, Chevron and Atlas Iron. Through the partnerships established with the corporate sector

we are undertaking research that increases our knowledge of what biodiversity we have and where it occurs, enabling us to develop management options in delivering enduring outcomes for conservation and ongoing economic development.

This year has also seen an expansion in climate change research with attendance of senior scientists at workshops on climate change adaptation hosted by the National Climate Change Adaptation Research Facility (NCCARF), and significant progress in collaborative research projects investigating the role of granite outcrops as refugia and the utility of models predicting climate change impacts on the biota.

A major focus of activity this year has been the long awaited move into the new Western Australian Conservation Science Centre (WACSC) at Kensington. This new building provides much needed new meeting room and cafeteria facilities for the department, and houses the central reception for the Kensington site. The central atrium area has been used for numerous departmental activities and functions, such as the Graduation and Awards Ceremony and celebrations for National Aboriginal and Islander Day of Celebration (NAIDOC) week. For Science Division, the WACSC is a state-of-the-art facility that houses the Western Australian Herbarium, the state's collection of 720,000 plant, algal and fungal specimens, DNA laboratories and the Western Australian Threatened Flora Seed Centre. Co-location of staff on one site facilitates greater interaction and integration, and has enabled the amalgamation of the three library collections into one Conservation Library providing improved access to biodiversity conservation information for all departmental staff.

The Perth Observatory has undertaken a review of operations and directions during the year. A workshop to gather input from partners and stakeholders in the astronomical community was held in February and led to the development of a strategic plan for the future direction and development of the Observatory.

The scientific work of the division would not be possible without the efficient support of the administrative staff, the work centre managers, and library staff. I would also like to acknowledge the valuable contribution of Dr David Coates and Dr Anne Mathews as Acting Directors of the Division during 2010/2011.

The requirement for scientific information is increasing and, given our finite capacity to meet this challenge, working in partnership is a cost-effective way to deliver science to meet the conservation needs of DEC. We look forward to continued productive collaborations with our internal and external partners to deliver effective conservation science for Western Australia.

Dr Margaret Byrne

Acting Director

July 2011

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VISION

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

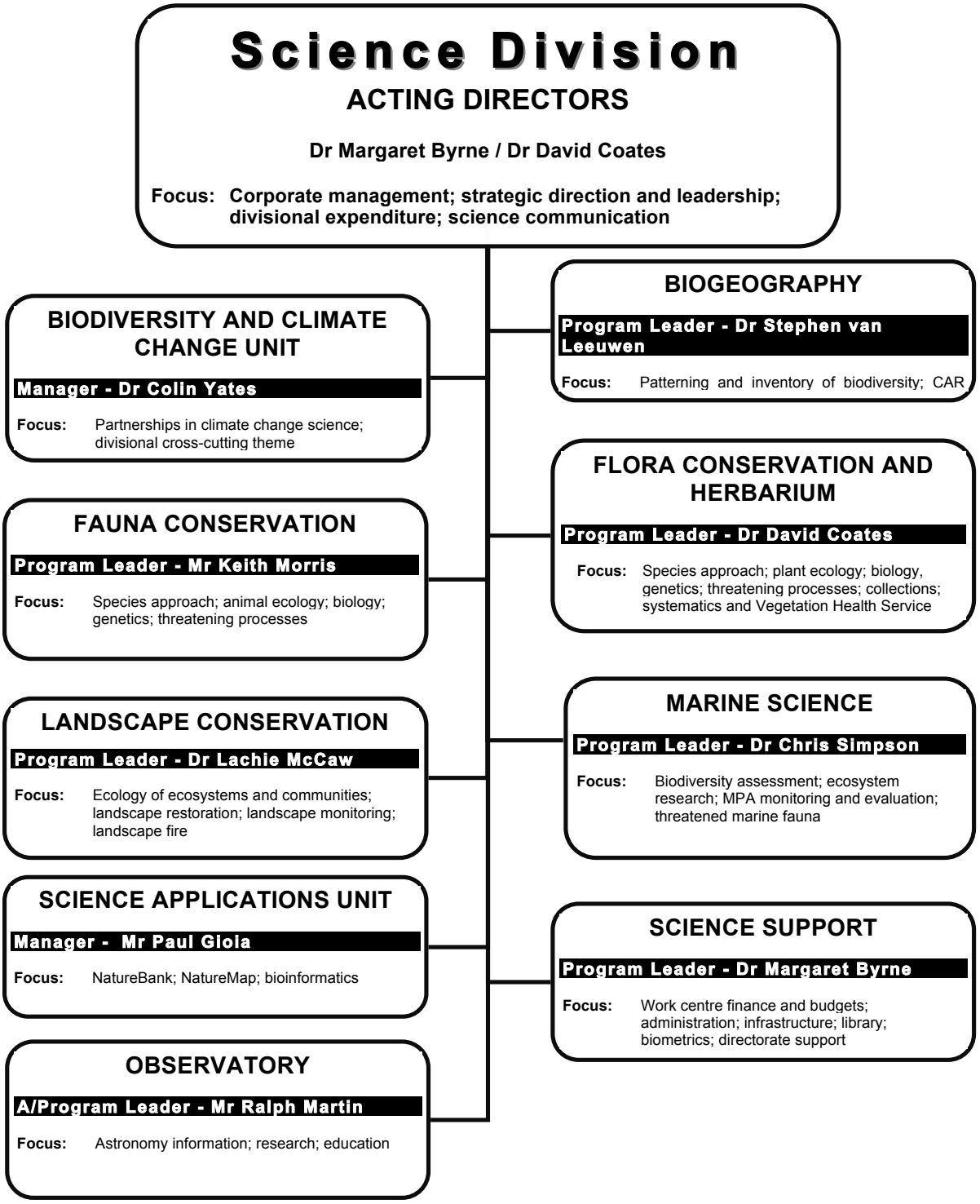
FOCUS AND PURPOSE

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

1. Abbott I (2010) Petals that endure (BOOK REVIEW). *History West* **49(11)**, p. 7.
2. Abbott I (2010) Scraps from the soil (BOOK REVIEW). *History West* **49(7)**, p. 6.
3. Abbott I (2011) The importation, release, establishment, spread and early impact on prey animals of the red fox, *Vulpes vulpes* in Victoria and adjoining parts of south-eastern Australia. *Australian Zoologist* **35**, 463-533.
4. Abbott I (2011) Renaming names. *Field Nats News* **210**, p. 4.
5. Alacs EA, Spencer PBS, de Tores PJ, Krauss SL (2011) Population genetic structure of island and mainland populations of the quokka, *Setonix brachyurus* (Macropodidae): a comparison of AFLP and microsatellite markers. *Conservation Genetics* **12**, 297-309.
6. Algar D (2010) That feral cat bait. *Bushland News* **75**, p. 10.
7. Algar D, Angus GJ, Brazell RI, Gilbert C, Withnell GB (2010) Eradication of feral cats on Faure Island, Western Australia. *Journal of the Royal Society of Western Australia* **93**, 133-140.
8. Algar D, Hilmer S, Onus M, Hamilton N, Moore J (2011) New national park to be cat free. *LANDSCOPE* **26(3)**, 39-45.
9. Algar D, Johnston M (2010) *Proposed management plan for cats and black rats on Christmas Island*. Department of Environment and Conservation, Kensington, Western Australia. 63 pp.
10. Algar D, Onus M, Hamilton N, Hilmer S (2010) That feral cat bait (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species* p. 4.
11. Andersen AN, Lanoue J. Radford I (2010) The ant fauna of the remote Mitchell Falls area of tropical north-western Australia: biogeography, environmental relationships and conservation significance. *Journal of Insect Conservation* **14**, 647-661.
12. Archibald RD, Bradshaw J, Bowen B, Close D, McCaw L, Drake P et al. (2010) Understorey thinning and burning trials are needed in conservation reserves: the case of tuart (*Eucalyptus gomphocephala* D.C.). *Ecological Management and Restoration* **11**, 108-112.
13. Batista V, Gould A, Dieters S, Dong S., Bond I, Beaulieu JP et al. [Martin R, Williams A] (2011) MOA-2009-BLG-387Lb: a massive planet orbiting an M dwarf. *Astronomy and Astrophysics* **529**, A102 (pp. 1-20).
14. Beeton B, Burbidge A, Grigg G, Harrison P, How R, Humphries B et al. [McKenzie N] (2010) Final report of the Christmas Island Expert Working Group to the Minister for Environment Protection, Heritage and the Arts. Christmas Island Expert Working Group, Brisbane. 262 pp.
15. Bell U (2010) A new native grass species. *Western Wildlife: Newsletter of the Land for Wildlife Scheme* **14(2)**, p. 7.
16. Bell U (2010) Some notes on growing native grasses. *Western Wildlife: Newsletter of the Land for Wildlife Scheme* **14(2)**, 3-5.
17. Bell U (2010) Some notes on growing native grasses. Pt 2. *Western Wildlife: Newsletter of the Land for Wildlife Scheme* **14(3)**, 8-9.
18. Bishop C (2010) Conservation of the graceful sun-moth. *Bushland News* **74**, p. 2.
19. Bishop CL, Wardell-Johnson GW, Williams MR (2010) Community-level changes in *Banksia* woodland following plant pathogen invasion in the southwest Australian floristic region. *Journal of Vegetation Science* **21**, 888-898.
20. Bishop C, Williams M, Mitchell D (2010) Conservation of graceful sun-moth habitat (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species*
21. Bishop C, Williams M, Mitchell D, Gamblin T (2010) Survey guidelines for the graceful sun-moth (*Synemon gratiosa*) and site habitat assessments.

Department of Environment and Conservation, Kensington, Western Australia. 20 pp.
22. Bishop C, Williams M, Mitchell D, Williams A, Fissioli J, Gamblin T (2010) Conservation of the graceful sun-moth (*Synemon gratiosa*): findings from the 2010 graceful sun-moth surveys and habitat assessments across the Swan, South West and southern Midwest regions: interim report, August 2010. Department of Environment and Conservation, Kensington, Western Australia. 30 pp.
23. Bondin A, Comer S, Burbidge A (2011) Conserving kyloring: the challenge to save Australia's newest parrot species from extinction. *Wingspan* **21(2)**, 18-20.
24. Bougher NL (2010) Fungi survey: Bold Park, 2010. Department of Environment and Conservation, Kensington, Western Australia. 16 pp.
25. Bougher NL (2010) Fungi survey: Kings Park and Botanic Garden 2010. Department of Environment and Conservation, Kensington, Western Australia. 21 pp.
26. Bougher N (2010) History of the study of Kings Park's fungi. *For People & Plants* **70**, 20-21.
27. Bougher N, Friend T (2010) Fungi nourish Gilbert's potoroo from the brink of extinction (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species* p. 6.
28. Brennan KEC , Moir ML, Wittkuhn RS (2011) Fire refugia: the mechanism governing animal survivorship within a highly flammable plant. *Austral Ecology* **36**, 131-141.
29. Bryant GL, Eden P, de Tores P, Warren K (2010) Improved procedure for implanting radio transmitters in the coelomic cavity of snakes. *Australian Veterinary Journal* **88**, 443-448.
30. Burbidge A (2010) Western white-naped honeyeater: a separate species. *Western Australian Bird Notes* **135**, p. 23.
31. Burbidge A (2011) Australia's western ground parrot: will it survive the ravages of introduced predators? Available at: http://bushwarriors.wordpress.com/2011/01/28/enigmatic-and-unusual-bird-on-the-bink-of-extinction-australia%e2%80%99s-western-ground-parrot-will-it-survive-the-ravages-of-introduced-predators-and-bushfires/. Bush Warriors, New York. 10 pp.
32. Burbidge A (2011) Book review: Parrots of the world. *Western Australian Bird Notes* **137**, 8-9.
33. Burbidge A, Comer S (2010) Island arks for rare Western Australians. *Wingspan. Supplement* **20**, p. 15.
34. Burbidge AH, Comer S, Danks A, Berryman A, Hamilton N (2010) Attempted re-introduction of the western bristlebird in south-western Australia. In *Global Re-Introduction Perspectives, 2010: Additional Case Studies from Around the Globe* (ed PS Soorae), pp. 171-175. IUCN SSC Re-Introduction Specialist Group, Abu Dhabi.
35. Burbidge A, Hamilton N, Comer S, Blythman M, Caton W, Pridham J, Danks A (2010) New and interesting bird records from Barrow Island. *Western Australian Bird Notes* **135**, 25-26.
36. Burbidge AH, Johnstone RE, Pearson DJ (2010) Birds in a vast arid upland: avian biogeographical patterns in the Pilbara region of Western Australia. *Records of the Western Australian Museum. Supplement* **78**, 247-270.
37. Burbidge AH, Maron M, Clarke MF, Baker J, Oliver DL, Ford G (2011) Linking science and practice in ecological research: how can we do it better? *Ecological Management and Restoration* **12**, 54-60.
38. Burbidge A, Mather S (eds) (2010) Western Australian bird notes: quarterly newsletter of Birds Australia Western Australia. No. 135, September 2010. 42 pp.
39. Burbidge A, Mather S (eds) (2010) Western Australian bird notes: quarterly newsletter of Birds Australia Western Australia. No. 136, December 2010. 38 pp.
40. Burbidge A, Mather S (eds) (2011) Western Australian bird notes: quarterly newsletter of Birds Australia Western Australia. No. 137, March 2011. 42 pp.
41. Burbidge A, Mather S (eds) (2011) Western Australian bird notes: quarterly newsletter of Birds Australia Western Australia. No. 138, June 2011. 42 pp.
42. Burbidge AH, Tiller C, Comer S, Algar D, Friend JA, Berryman A (2010) Cost-effective approaches to threatened species management: the south coast integrated fauna recovery program (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government*

Research into Threatened Species p. 8.
43. Burrows N (2011) From fire science to fire management to protect communities and conservation values. In *Wildfire 2011: the 5th International Wildland Fire Conference, 9-13 May 2011, South Africa: Living with Fire: Addressing Global Change through Integrated Fire Management: Sun City, South Africa, 9-13 May 2011* pp. 1-10. Conference Organising Committee, Sun City.
44. Burrows N (2011) Using observers on horseback to monitor bilby (*Macrotis lagotis*) and other animal activity at Lorna Glen: results of a trial carried out 29-31 March 2011. Department of Environment and Conservation, Kensington, Western Australia. 11 pp.
45. Burrows N, Butler R (2011) A fire management plan for Lorna Glen (Matuwa) and Earaheedy (Karara Karara) 2011-2015. Department of Environment and Conservation, Kensington, Western Australia. 33 pp.
46. Burrows N, Liddelow G (2011) Lorna Glen introduced predator monitoring: data summary, 23-27 June 2011. Department of Environment and Conservation, Kensington, Western Australia. 4 pp.
47. Butcher R (2010) *Tetratheca* sp. *Mt Solus* (F. Obbens 307/98) (Elaeocarpaceae) is not distinct from *Tetratheca affinis*. *Nuytsia* **20**, 319-320.
48. Byrne M (2010) Species response to climate change—can the past inform the future? Available at: http://www.dec.wa.gov.au/component/option,com_docman/task,doc_download/gid,4667/Itemid,/ Department of Environment and Conservation, Western Australia, Science Division, Information Sheet **36/2010**, Kensington, Western Australia. 2 pp.
49. Byrne M, Coates D, Millar M, Walker E, Yates C, Gibson N et al [Elliott C, Butcher R, Sampson J] (2010) Conservation genetics of threatened species in the diverse flora of Western Australia (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species* p. 8.
50. Byrne M, Stone L (2011) The need for duty of care when introducing new crops for agriculture. *Current Opinion in Environmental Sustainability* **3**, 50-54.
51. Calado A, Huisman JA (2010) Commentary: Gómez, F., Moreira, D. & López-García, P. (2010). *Neoceratium* gen. nov., a new genus for all marine species currently assigned to *Ceratium* (Dinophyceae). Protist 161: 35-54. *Protist* **161**, 517-519.
52. Clarke A, Lane J, Jaensch R (2011) Surveys of waterbirds in selected wetlands of south-western Australia in spring-summer 2009-10, with further assessment of changes in habitat and waterbird usage over 2-3 decades. Department of Environment and Conservation, Busselton. 109 pp.
53. Coates D (2010) Threatened flora research in the Department of Environment and Conservation: preventing extinction and enhancing recovery (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australia Government Research into Threatened Species* p. 9.
54. Coates DJ, McArthur S, Byrne M (2010) Genetic consequences of population loss and reintroduction in the rare geographically disjunct *Banksia brownii* following pathogen driven local extinction (ABSTRACT). In *Genetics Society of AustralAsia 2010: Annual Conference, Canberra 4-8 July: Programme and Abstracts* 5-6.
55. Cochrane A, Barrett S, Crane C, Dunne C, Hartley R, Freebury G (2011) Last chance to see: banksias of the south coast of Western Australia. *LANDSCOPE* **26(4)**, 17-22.
56. Cochrane JA, Barrett S, Monks L, Dillon R (2010) Partnering conservation actions: *inter situ* solutions to recover threatened species in south-west Western Australia. *Kew Bulletin* **65**, 655-662.
57. Cochrane, A, Comer S, Collins P, Pridham J, Tiller C (2010) Michaelmas Island, King George Sound. *LANDSCOPE* **26(2)**, 59-61.
58. Cochrane A, Crawford A, Monaghan A, Dudley S, Elkins B, Barrett L, Schreck S (2010) Integrating seed science into seed banking provides critical support for threatened flora conservation (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species.*
59. Cochrane A, Dillon R, Barrett S, Adams E (2010) Orchard bears fruit.

LANDSCOPE **26(1)**, 6-8.
60. Cole AJ, Lawton RJ, Pratchett MS, Wilson SK (2011) Chronic coral consumption by butterflyfishes. *Coral Reefs* **30**, 85-93.
61. Comer S, Burbidge A, Tiller C, Berryman A, Utber D (2010) Heeding kyloring's warning: south coast species under threat. *LANDSCOPE* **26(1)**, 48-53.
62. Comer S, Butler S, Burbidge A (2011) Ground parrots and bushfire, again! *Western Australian Bird Notes* **138**, 17-18.
63. Comer SJ, Cowen S, Berryman A, Tiller C (2010) Noisy scrub-bird research and recovery program 1964-2010 (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species* p. 10.
64. Comer S, Danks A, Burbidge AH, Tiller C (2010) The history and success of noisy scrub-bird re-introductions in Western Australia, 1983-2005. In *Global Re-Introduction Perspectives, 2010: Additional Case Studies from Around the Globe* (ed PS Soorae), pp. 187-192. IUCN SSC Re-Introduction Specialist Group, Abu Dhabi.
65. Crane CE, Barrett S, Shearer BL, Dunne CP (2010) Comparison of the impacts of plant canker disease and climate on Proteaceae and evaluation of selected fungicides as a management tool for canker control in the threatened flora *Banksia verticillata* and *Lambertia orbifolia* (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species* p. 11.
66. Cranfield R (2010) Key to moss groups of Western Australia. Department of Environment and Conservation, Manjimup. 20 pp.
67. Cranfield RJ (2010) Pictorial lichen glossary and key to genera: a guide for those just starting. Department of Environment and Conservation, Manjimup. 116 pp.
68. Cranfield RJ, Hislop M, Macfarlane TD (2010) *Logania sylvicola* (Loganiaceae), a new species from south-west Western Australia. *Nuytsia* **20**, 271-275.
69. Crawford A, Cochrane A (2010) Seed saviours ensure all is not lost. *Hort Journal Australia* **3(3)**, 6-7.
70. Crawford AD, Plummer JA, Probert RJ, Steadman KJ (2011) The influence of cone age on the relative longevity of *Banksia* seeds. *Annals of Botany* **107**, 303-309.
71. Davis RW, Butcher R (2010) Re-evaluation of *Ptilotus polystachyus* sens.lat. (Amaranthaceae) and creation of the new combination *Ptilotus giganteus*. *Nuytsia* **20**, 217-227.
72. Davis RW, Butcher R (2010) The status of infraspecific taxa and new subspecies in *Ptilotus stirlingii* (Amaranthaceae). *Nuytsia* **20**, 261-270.
73. Davis RW, Butcher R (2011) Valid publication of *Ptilotus stirlingii* ssp. *australis* (Amaranthaceae). *Nuytsia* **21**, 31-32.
74. Davison E (2010) Managing tar spot disease of myrtle hakea. *Western Wildlife: Newsletter of the Land for Wildlife Scheme* **14(1)**, 4-5.
75. Davison EM, Tay FCS (2010) Management of tar spot disease caused by *Phyllachora grevilleae* ssp. *grevilleae* on *Hakea myrtoides* (Proteaceae). *Australian Journal of Botany* **58**, 392-397.
76. De Tores PJ, Elscot S (2010) Estimating the population size of a threatened arboreal marsupial: use of distance sampling to dispense with ad hoc survey techniques. *Wildlife Research* **37**, 512-523.
77. De Tores P, Hayward M, Spencer P, Bain K, Gibson L (2010) The quokka, *Setonix brachyurus* (Quoy and Gaimard, 1830) (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species* 12-13.
78. De Tores P, Marlow N, Algar D, Morris K, Glen A, Sutherland D et al. (2010) Predation by foxes and cats, the ubiquitous threat to biodiversity conservation in Australia: is it made worse or ameliorated by mesopredator release? (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species* 13-14.
79. De Tores P, Wayne A, Warren K, Calver M, Fleming P, Spencer P et al. [Clarke J, Grimm H, Bryant G, Elscot S] (2010) The western ringtail possum, *Pseudocheirus occidentalis* (Thomas, 1888) (ABSTRACT). In *Threatened Species*

Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species p. 12.
80. DEC (2010) Conservation values of the Whicher Scarp: report of the Expert Panel. Department of Environment and Conservation, Kensington, Western Australia. 65 pp.
81. Dixon R, Huisman J (2010) Species boundaries within *Sargassum* (Fucales: Phaeophyceae) of Western Australia (ABSTRACT). In *ASPAB Conference 2010: Rottnest Island, Western Australia, 15th-18th November* p. 21.
82. Durrant B (2010) Spineless impact assessments. *LANDSCOPE* **26(2)**, 52-58.
83. Durrant BJ, Harvey MS, Framenau VW, Ott R, Waldock JM (2010) Patterns in the composition of ground-dwelling spider communities in the Pilbara bioregion, Western Australia. *Records of the Western Australian Museum. Supplement* **78**, 185-204.
84. Eden P, Reiss A, Nicolls P, Wayne A (2010) Investigation of skin diseases observed in woylies (*Bettongia penicillata ogilbyi*) from the upper Warren region, Western Australia. In *In situ* conservation funding: annual report to Woylie Conservation Action pp. 6-16. Department of Environment and Conservation, Manjimup.
85. Faivre N, Roche P, Boer MM, McCaw L, Grierson PF (2011) Characterization of landscape pyrodiversity in Mediterranean ecosystems: contrasts and similarities between south-western Australia and south-eastern France. *Landscape Ecology* **26**, 557-571.
86. Farmer BM, Wilson S (2011) Diet of finfish targeted by fishers in north west Australia and the implications for trophic cascades. *Environmental Biology of Fishes* **91**, 78-85.
87. Farr J (2010) Bullseye borer (*Phoracantha acanthocera*) in karri. Available at: http://www.dec.wa.gov.au/component/option,com_docman/task,doc_download/gid,4669/Itemid,/ Department of Environment and Conservation, Western Australia, Science Division, Information Sheet **37/2010**, Kensington, Western Australia. 2 pp.
88. Farr J, Wills A (2010) 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, Western Australia. 7 pp.
89. Flann C, Wilson PG, Wieringa JJ (2010) Typification of *Gnaphalium collinum* var. *monocephalum* (Gnaphalieae: Asteraceae) and clarification of related material. *Nuytsia* **20**, 1-5.
90. Fouqué P, Heyrovský D, Dong S, Gould A, Udalski A, Albrow MD et al. [Williams A, Martin R] (2010) OGLE 2008–BLG–290: an accurate measurement of the limb darkening of a galactic bulge K Giant spatially resolved by microlensing. *Astronomy and Astrophysics* **518**, A51 (pp. 1-12).
91. Frew DJ, Madsen GJ, O'Toole SJ, Parker QA (2010) PHL 932: when is a planetary nebula not a planetary nebula? *Publications of the Astronomical Society of Australia* **27**, 203-209.
92. Friend T (2010) Conservation of Australian mammals: successes, failures and future challenges (ABSTRACT). *Australian Mammal Society Newsletter* **Oct**, p. 27.
93. Friend T (2010) The role of research in numbat recovery: no time to rest on laurels (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species* p. 15.
94. Friend T (2010) Supporting the recovery of the world's rarest marsupial, Gilbert's potoroo, with science: past and current research and future directions (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species* p. 15.
95. Fukiharu T, Bougher NL, Buchanan PK, Suzuki A, Tanaka C, Sagara N (2011) *Coprinopsis austrophlyctidospora* sp. nov., an agaric ammonia fungus from southern hemisphere plantations and natural forests. *Mycoscience* **52**, 137-142.
96. Gamblin T, Bishop C, Williams M, Williams A (2011) Graceful sun-moth (*Synemon gratiosa*). Department of Environment and Conservation, Western Australia, Science Division, Information Sheet **41**, Department of Environment and Conservation, Kensington, Western Australia. 2 pp.
97. George AS, Barrett MD (2010) Two new

taxa of *Verticordia* (Myrtaceae: Chamelaucieae) from south-western Australia. *Nuytsia* **20**, 309-318.
98. George AS, Gibson N (2010) A revision of *Calothamnus quadrifidus* (Myrtaceae). *Nuytsia* **20**, 57-77.
99. Gibson LA (2011) The importance of incorporating imperfect detection in biodiversity assessments: a case study of small mammals in an Australian region. *Diversity and Distributions* **17**, 613-623.
100. Gibson L, Köhler F, Kessner V (2010) Diversity hot spot revealed: land snails of the Kimberley. *LANDSCOPE* **26(1)**, 26-31.
101. Gibson L, McKenzie N (2010) Environmental associations of small ground-dwelling mammals in the Pilbara. Available at: http://www.dec.wa.gov.au/component/option,com_docman/task,doc_download/gid,4668/Itemid,/ Department of Environment and Conservation, Western Australia, Science Division, Information Sheet **38/2010**, Kensington, Western Australia. 2 pp.
102. Gibson L, McNeill A, de Tores P, Wayne A, Yates C (2010) Will future climate change threaten a range restricted endemic species, the quokka (*Setonix brachyurus*), in south-west Australia? *Biological Conservation* **143**, 2453-2461.
103. Gibson N (2010) How rare and threatened flora management is enhanced by vegetation survey (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species* p. 16.
104. Gibson N (2011) Where might metallophytes be hiding in the flora of Western Australia (ABSTRACT). In *Metallophyte Plants: a Threatened and Unrealised Resource Hidden in our Biodiversity: an Institute of Advanced Studies Workshop, 8-10 February 2011, University of Western Australia* p. 1.
105. Gibson N, Sheehy N, Meissner R, Markey A, Thompson W (2010) Banded iron formation (BIF) ranges. Available at: http://naturemap.dec.wa.gov.au/Forms/Theme_BIF/bif_default.aspx p. 1. Department of Environment and Conservation, Kensington, Western Australia.
106. Gibson N, Yates CJ, Dillon R (2010) Plant communities of the ironstone ranges of south western Australia: hotspots for plant diversity and mineral deposits. *Biodiversity and Conservation* **19**, 3951-3962.
107. Glen AS, Pennay M, Dickman CR, Wintle BA, Firestone KB (2011) Diets of sympatric native and introduced carnivores in the Barrington Tops, eastern Australia. *Austral Ecology* **36**, 290-296.
108. Glen AS, Wayne A, Maxwell M, Cruz J (2010) Comparative diets of the chuditch, a threatened marsupial carnivore, in the northern and southern jarrah forests, Western Australia. *Journal of Zoology* **282**, 276-283.
109. Gosper CR, Prober SM, Yates CJ (2010) Chaining and burning modifies vegetation structure, fuel and post-disturbance sprouting capacity. *Rangelands Ecology and Management* **63**, 588-592.
110. Gosper C, Yates C, Prober S (2010) To burn or not to burn: challenging decisions in fragmented landscapes. *LANDSCOPE* **26(2)**, 46-51.
111. Gosper C, Yates C, Prober S (2010) Using fruit crop and mortality to determine appropriate fire return intervals. Available at: http://www.dec.wa.gov.au/component/option,com_docman/task,doc_download/gid,4817/Itemid,/ Department of Environment and Conservation, Western Australia, Science Division, Information Sheet **39/2010**, Kensington, Western Australia. 2 pp.
112. Gosper C, Yates C, Prober S (2011) Restoring an appropriate fire regime to fragmented vegetation: a vital attributes approach. Paper presented at the 4th International Fire Ecology and Management Congress: Fire as a Global Process Available at: http://fireecology.net/past-conferences/10-4thcongress.html Department of Environment and Conservation, Kensington, Western Australia.
113. Gosper CR, Yates CJ, Prober SM, Williams MR (2011) Fire does not facilitate invasion by alien annual grasses in an infertile Australian agricultural landscape. *Biological Invasions* **13**, 533-544.
114. Gould A, Dong S, Gaudi BS, Udalski A, Bond IA, Greenhill J et al. [Martin R, Williams J] (2010) Frequency of solar-like systems and of ice and gas giants beyond the snow line from high-magnification microlensing events in

2005-2008. *Astrophysical Journal* **720**, 1073-1089.
115. Gould JS, McCaw WL, Cheney NP (2011) Quantifying fine fuel dynamics and structure in dry eucalypt forest (*Eucalyptus marginata*) in Western Australia for fire management. *Forest Ecology and Management* **262**, 531–546.
116. Gould J, McCaw L, Cruz M, Anderson W (2011) How good are fire behaviour models? Validation of eucalypt forest fire spread model. In *Wildfire 2011: the 5th International Wildland Fire Conference, 9-13 May 2011, South Africa: Living with Fire: Addressing Global Change through Integrated Fire Management: Sun City, South Africa, 9-13 May 2011* pp. 1-6. Conference Organising Committee, Sun City.
117. Graham NAJ, Chabanet P, Evans RD, Jennings S, Letourneur Y, MacNeil MA et al. [Wilson SK] (2011) Extinction vulnerability of coral reef fishes. *Ecology Letters* **14**, 341-348.
118. Guthrie NA, Weir T, Will K (2010) Localised and regional patterns in ground-dwelling beetle assemblages in a semi-tropical arid zone environment. *Records of the Western Australian Museum. Supplement* **78**, 169-184.
119. Guthrie NA, Weir T, Will K (2011) Patterns of richness: ground-dwelling beetles of the Pilbara (POSTER). In *Australian Entomology Society Conference 26th-30th September 2010* p. 1. Conference Organising Committee, Perth.
120. Hallegraeff GM, Bolch CJS, Huisman JM, de Salas MF (2010) Planktonic dinoflagellates. In *Algae of Australia: Phytoplankton of Temperate Coastal Waters* pp. 145-212. CSIRO Pub., Canberra.
121. Hamilton N, Onus M, Forrest K (2010) Fighting back: mulgaras return. *LANDSCOPE* **26(2)**, 6-8.
122. Hamilton N, Rolfe J (2011) Assessment of introduced predator presence within the Perup Sanctuary, Western Australia. Department of Environment and Conservation, Woodvale, Western Australia. 7 pp.
123. Harding D (ed) (2010) Conservation science Western Australia. Volume seven, number three, September 2010. pp. 451-632. Department of Environment and Conservation, Kensington, Western Australia.
124. Hardwick KA, Fiedler P, Lee LC, Pavlik B, Hobbs RJ, Aronson J et al. [Coates D] (2011) The role of botanic gardens in the science and practice of ecological restoration. *Conservation Biology* **25**, 265-275.
125. Hart F, Huisman JM (2010) The taxonomy and pest potential of the genus *Codium* in Western Australia (ABSTRACT). In *ASPAB Conference 2010: Rottnest Island, Western Australia, 15th-18th November* p. 28.
126. Hart R (2010) 2010 fungi surveys. *Bushland News* **75**, p. 9.
127. Hendrati R, Byrne M, Barbour E, Plummer J (2011) Effect of genetic relatedness among parents on gain in salt tolerance in progeny of crosses of *Eucalyptus occidentalis*. *Silvae Genetica* **60(2)**, 45-55.
128. Hilmer SS, Algar D, Johnston M (2010) Opportunistic observation of predation of loggerhead turtle hatchlings by feral cats on Dirk Hartog Island, Western Australia. *Journal of the Royal Society of Western Australia* **93**, 141-146.
129. Hilmer S, Algar D, Plath M, Schleucher E (2010) Relationship between daily body temperature and activity patterns of free-ranging feral cats in Australia. *Journal of Thermal Biology* **35**, 270-274.
130. Hislop M (2010) A new locally endemic species of *Acrotriche* (Ericaceae: Styphelioideae: Styphelieae) from the Ravensthorpe area. *Nuytsia* **20**, 19-25.
131. Hislop M, Rye BL (2010) Two new, glaucous-leaved species of *Isopogon* (Proteaceae: Proteoideae: Leucadendreae) from south-western Australia. *Nuytsia* **20**, 169-181.
132. Hollis JJ, Anderson WR, McCaw WL, Cruz MG, Burrows ND, Ward B et al. (2011) The effect of fireline intensity on woody fuel consumption in southern Australian eucalypt forest fires. *Australian Forestry* **74**, 81-96.
133. Hollis JJ, Matthews S, Anderson WR, Cruz MG, Burrows ND (2011) Behind the flaming zone: predicting woody fuel consumption in eucalypt forest fires in southern Australia. *Forest Ecology and Management* **261**, 2049-2067.
134. Hollis JJ, Matthews S, Ottmar RD, Prichard SJ, Slijepcevic A, Burrows ND et al. [Ward B] (2010) Testing woody fuel consumption models for application in Australian southern eucalypt forest fires. *Forest Ecology and Management* **260**, 948-964.
135. Hooper RJ, Wills A, Shearer BL, Sivasithamparam K (2010) A

redescription and notes on biology of *Cisseis fascigera* Obenberger (Coleoptera: Buprestidae) on declining *Eucalyptus wandoo* in south-western Australia. *Australian Journal of Entomology* **49**, 234-244.
136. Huisman JM, de Clerck O, Prud'Homme van Reine WF, Borowitzka MA (2010) *Spongophloea*, a new genus of red algae based on *Thamnoclonium* sect. *Nematophorae* Weber-van Bosse (Halymeniales) (ABSTRACT). In *ASPAB Conference 2010: Rottnest Island, Western Australia, 15th-18th November* p. 31.
137. Huisman JM, de Clerck O, Prud'homme van Reine WF, Borowitzka MA (2011) *Spongophloea*, a new genus of red algae based on *Thamnoclonium* sect. *Nematophorae* Weber-van Bosse (Halymeniales). *European Journal of Phycology* **46**, 1-15.
138. Huisman J, Dixon R (2011) Northern exposure. *LANDSCOPE* **26(4)**, 10-16.
139. Huisman JA, Kendrick AJ, Rule MJ (2011) Benthic algae and seagrasses of the Walpole and Nornalup Inlets Marine Park. *Journal of the Royal Society of Western Australia* **94**, 29-44.
140. Huntley B, Barnard P, Altwegg R, Chambers L, Coetzee B, Gibson L et al. (2010) Beyond bioclimatic envelopes: dynamic species' range and abundance modelling in the context of climatic change. *Ecography* **33**, 621-626.
141. Hwang K-H, Udalski A, Han C, Ryu Y-H, Bond IA, Beaulieu J-P et al. [Martin R, Williams A] (2010) OGLE-2005-BLG-153: microlensing discovery and characterization of a very low mass binary. *Astrophysical Journal* **723**, 797-802.
142. Hyder BM, Dell J, Cowan M (eds) (2010) Technical guide: terrestrial vertebrate fauna surveys for environmental impact assessment: technical report of the Environmental Protection Authority and the Department of Environment and Conservation. Environmental Protection Authority, Perth. 47 pp.
143. Johnson B (2010) New island home. *LANDSCOPE* **26(2)**, 20-26.
144. Johnson B (2011) Rakali: the Aussie otter. *LANDSCOPE* **26(3)**, 6-9.
145. Johnson B, Morris K (2010) Recovery of the chuditch, *Dasyurus geoffroii* (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australia Government Research into Threatened Species* p. 17.
146. Johnson B, Reaveley A (2011) Dry times ahead: the future for fauna of the Gnangara Mound. *LANDSCOPE* **26(4)**, 56-61.
147. Joseph L, Burbidge A, Murphy S, Clarke R (2010) Night shift. *Wingspan* **20(4)**, 44-45.
148. Jung T, Stukely MJC, Hardy GE St J, White D, Paap T, Dunstan WA, Burgess TI (2011) Multiple new *Phytophthora* species from ITS clade 6 associated with natural ecosystems in Australia: evolutionary and ecological implications. *Persoonia* **26**, 13-39.
149. Keighery B, Keighery G (2010) Composition, biology, phytogeography and conservation of Western Australian Asteraceae (ABSTRACT). In *2010 Australian Systematic Botany Society Conference: Lincoln University, Canterbury, New Zealand, 29 November-3 December 2010: Systematic Botany Across the Ditch: Links Between Australia and New Zealand* p. 42.
150. Keighery B, Keighery G (2010) Western Australia's diverse wetland plant communities and climate change (ABSTRACT). In *Climate Change and Western Australian Wetlands and Waterways: Current Knowledge and Future Directions: Symposium, July 6th 2010, Perth Western Australia: Program and Abstracts* p. 17.
151. Keighery G (2010) The naturalised vascular plants of the Pilbara region, Western Australia. *Records of the Western Australian Museum. Supplement* **78**, 299–311.
152. Keighery G (2010) A new species of *Petrophile* (Proteaceae) from the Whicher Range. *Western Australian Naturalist* **27**, 103-106.
153. Keighery G (2010) Vascular flora of Eucla National Park. *Western Australian Naturalist* **27**, 150-159.
154. Keighery G (2010) Weeds and threatened flora (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species* 18-19.
155. Keighery G (2010) Weeds of the Nullarbor in Western Australia. *Western Australian Naturalist* **27**, 160-167.
156. Keighery G (2011) *Prunus* (Rosaceae or Amygalaceae) in Western Australia. *Australian Systematic Botany Newsletter* **144(5)**, 36-37.

157. Keighery G (2011) *Psylliostachys* (Plumbaginaceae) in Western Australia. *Australian Systematic Botany Newsletter* **144(5)**, p. 35.
158. Keighery G, Keighery B (2010) Taxonomy of *Amblysperma*/*Trichocline* (Asteraceae: Mutsiaeae): Western Australia's South American link (ABSTRACT). In *2010 Australian Systematic Botany Society Conference: Lincoln University, Canterbury, New Zealand, 29 November-3 December 2010: Systematic Botany Across the Ditch: Links Between Australia and New Zealand* p. 43.
159. Keighery G, Keighery B (2011) Hidden treasures: documenting localised variants of the flora of the Swan Coastal Plain. *Australasian Plant Conservation* **19**, 19-20.
160. Keighery G, Keighery B (2011) Hidden treasures: documenting localised variants of the flora of the Swan Coastal Plain (ABSTRACT). In *Australian Network for Plant Conservation Conference, Perth* p. 1.
161. Keighery G, Keighery B (2011) Pauline Fairall (Bond): a botanist of two continents. *Australian Systematic Botany Society Newsletter* **144(5)**, 27-28.
162. Keighery G, Lyons M, Gibson N, Keighery B (2010) Vascular flora of the Margaret River Plateau national parks, conservation parks and state forest, south-western Western Australia. *Conservation Science Western Australia* **7**, 481-502.
163. Keighery G, Muir W (2010) Checklists of the vascular plants of the deltaic islands of the Peel Estuary. *Western Australian Naturalist* **27**, 107-125.
164. Kinal J, Stoneman GL (2011) Hydrological impact of two intensities of timber harvest and associated silviculture in the jarrah forest in south-western Australia. *Journal of Hydrology* **399**, 108-120.
165. Klunzinger M, Pinder A, Cale D, Lymbery A (2011) Piggyback on a fish: the marsupial freshwater mussel tells it tale. *LANDSCOPE* **26(4)**, 46-47.
166. Knight KJ, Brims MH (2010) Myxomycota census of Western Australia. *Nuytsia* **20**, 283-307.
167. Lane JAK, Clarke AG, Winchcombe YC (2010) South-west wetlands monitoring program report, 1977-2009. Department of Environment and Conservation, Busselton. 149 pp.
168. Lane JAK, Clarke AG, Winchcombe YC (2011) Depth, salinity and temperature profiling of Vasse-Wonnerup wetlands in 1998-2000. 73 pp.
169. Lane JAK, Clarke AG, Winchcombe YC (2011) South-west wetlands monitoring program report, 1977-2010. Department of Environment and Conservation, Busselton. 156 pp.
170. Leung A, Pinder A, Edward D (2011) Photographic guide and keys to the larvae of Chironomidae (Diptera) of south-west Western Australia: key to subfamilies and Tanypodinae. Draft v1. Department of Environment and Conservation, Woodvale, Western Australia. 31 pp.
171. Lin S-M, Yang S-Y, Huisman JM (2011) Systematic revision of the genera *Liagora* and *Izziella* (Liagoraceae: Rhodophyta) from Taiwan based on molecular analyses and carposporophyte development, with the description of two new species. *Journal of Phycology* **47**, 352-365.
172. Macfarlane TD, Case AL (2011) *Wurmbea fluviatilis* (Colchicaceae), a new riverine species from the Gascoyne region of Western Australia. *Nuytsia* **21**, 25-30.
173. Markey AS, Dillon SJ (2010) Flora and vegetation of the banded iron formations of the Yilgarn Craton: Gullewa. *Conservation Science Western Australia* **7**, 531-556.
174. Markey AS, Dillon SJ (2010) Flora and vegetation of the banded iron formations of the Yilgarn Craton: the Booylgoo Range. *Conservation Science Western Australia* **7**, 503-529.
175. Markey A, Wilkins C, Allen J, Kern S, Rathbone D (2011) Report on the conservation status of 74 taxa from the Ravensthorpe Range. Department of Environment and Conservation, Kensington, Western Australia. 214 pp.
176. Maslin B (2010) National Wattle Day. *Bushland News* **74**, p. 9.
177. Matheny PB, Bougher NL (2010) Type studies of Australian species of *Inocybe* (Agaricales). *Muelleria* **28**, 87-104.
178. McArthur S, Coates D (2010) Characterisation of microsatellite markers for the rare and critically endangered *Banksia brownii* (Proteaceae). *Conservation Genetic Resources* **2**, 177-179.
179. McCaw L (2010) Implications of climate change for fire management in Mediterranean ecosystems in the south-west of Western Australia (ABSTRACT).

International Forestry Review **12(5)**, 55-56.
180. McCaw L, Bannister T, Sullivan A, Tolhurst K (2010) Weather and fire behaviour during the Victorian bushfires of 7 February 2009 (ABSTRACT). *International Forestry Review* **12(5)**, p. 57.
181. McCaw L, Robinson R (2010) ForestCheck: monitoring biodiversity in jarrah (*Eucalyptus marginata*) forest managed for timber harvesting (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species* p. 20.
182. McCaw L, Wittkuhn R (2011) Southern forest and shrubland mosaic. Fire Management Guideline **E8**, Department of Environment and Conservation, Kensington, Western Australia. 19 pp.
183. McMullan-Fisher SJM, May TW, Robinson RM, Bell TL, Lebel T, Catcheside P et al. (2011) Fungi and fire in Australian ecosystems: a review of current knowledge, management implications and future directions. *Australian Journal of Botany* 70-90.
184. Meissner R, Owen G (2010) Flora and vegetation of banded iron formations of the Yilgarn Craton: Brooking Hills area. *Conservation Science Western Australia* **7**, 571-581.
185. Meissner R, Owen G (2010) Flora and vegetation of banded iron formations of the Yilgarn Craton: Mt Ida greenstone belt and Mt Hope. *Conservation Science Western Australia* **7**, 583-592.
186. Meissner R, Owen G (2010) Flora and vegetation of banded iron formations of the Yilgarn Craton: western Narryer terrane. *Conservation Science Western Australia* **7**, 617-628.
187. Meissner R, Wright J (2010) Flora and vegetation of banded iron formations of the Yilgarn Craton: Barloweerie and Twin Peaks greenstone belts. *Conservation Science Western Australia* **7**, 557-570.
188. Meissner R, Wright J (2010) Flora and vegetation of banded iron formations of the Yilgarn Craton: Perseverance greenstone belt. *Conservation Science Western Australia* **7**, 593-604.
189. Meissner R, Wright J (2010) Flora and vegetation of banded iron formations of the Yilgarn Craton: south Illaara greenstone belt. *Conservation Science Western Australia* **7**, 605-616.
190. Millar MA, Byrne M, Coates DJ (2010) The maintenance of disparate levels of clonality, genetic diversity and genetic differentiation in disjunct subspecies of the rare *Banksia ionthocarpa*. *Molecular Ecology* **19**, 4127-4227.
191. Millar MA, Byrne M, O'Sullivan W (2011) Defining entities in the *Acacia saligna* (Fabaceae) species complex using a population genetics approach. *Australian Journal of Botany* **59**, 137-148.
192. Miller E, Dunlop J, Morris K (2010) Rangelands restoration: fauna recovery at Lorna Glen, Western Australia: progress report, August 2008-June 2010. Department of Environment and Conservation, Woodvale, Western Australia. 23 pp.
193. Monks L, Dillon R, Coates D, Yates C, Barrett S, Cochrane A et al. (2010) Experimental threatened flora translocations and determining criteria to assess translocation success (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species* p. 22.
194. Mora C, Aburto-Oropeza O, Ayala Bocos A, Ayotte PM, Bank S, Bauman AG et al. [Wilson SK] (2011) Global human footprint on the linkage between biodiversity and ecosystem functioning in reef fishes. *PLoS Biology* **9**, 1-9.
195. Morris KD, Dunlop J (2010) Fauna reconstruction in the Western Australian rangelands (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species* p. 23.
196. Morris K, Johnson B (2010) Exotic rodent eradication plans for several islands off the Western Australian coast: Adele Island, Long Island and Sunday Island (west Kimberley), Three Bays Island and Faure Island (Shark Bay), Direction Island (Cocos-Keeling group). Department of Environment and Conservation, Woodvale, Western Australia. 25 pp.
197. Morris K, Johnson B, Muir B (2010) Fauna recovery in the wheatbelt. *LANDSCOPE* **26(1)**, 56-61.
198. Murphy SA, Joseph L, Burbidge AH, Austin J (2011) A cryptic and critically endangered species revealed by mitochondrial DNA analyses: the western ground parrot. *Conservation Genetics* **12**, 595-600.

199. O'Donnell AJ, Boer MM, McCaw WL, Grierson PF (2011) Vegetation and landscape connectivity control wildfire intervals in unmanaged semi-arid shrublands and woodlands in Australia. *Journal of Biogeography* **38**, 112-124.
200. Oberoi D, Matthews LD, Cairns IH, Emrich D, Lobzin V, Lonsdale CJ et al. [Williams A] (2011) First spectroscopic imaging observations of the sun at low radio frequencies with the Murchison widefield array prototype. *Astrophysical Journal Letters* **728**, L27 (1-15).
201. Onton K, Page C, Wilson S, Neale S, Armstrong S (2010) Distribution and drivers of coral disease at Ningaloo Reef. Poster presented at the 85th annual Australian Coral Reef Society meeting, Coffs Harbour. (POSTER) In *Australian Coral Reef Society meeting, Coffs Harbour* Department of Environment and Conservation, Kensington, Western Australia. 1 poster.
202. Onton K, Page CA, Wilson SK, Neale S, Armstrong S (2011) Distribution and drivers of coral disease at Ningaloo reef, Indian Ocean. *Marine Ecology Progress Series* **433**, 75-84.
203. Onus M, Rolfe J (2011) Removal of feral cats within the fenced area at Big Lagoon, Peron Peninsula. Department of Environment and Conservation, Kensington, Western Australia. 14 pp.
204. Onus ML, Rolfe JK, Algar D (2011) Assessment of feral cat abundance and control options at Barrick, Granny Smith, May 2011. Department of Environment and Conservation, Woodvale, Western Australia. 16 pp.
205. Ord SM, Mitchell DA, Wayth RB, Greenhill LJ, Bernardi G, Gleadow S et al. [Williams A] (2010) Interferometric imaging with the 32 element Murchison wide-field array. *Publications of the Astronomical Society of the Pacific* **122**, 1353-1366.
206. Pacioni C, Wayne AF, Spencer PBS (2011) Effects of habitat fragmentation on population structure and long-distance gene flow in an endangered marsupial: the woylie. *Journal of Zoology* **283**, 98-107.
207. Pan S, Thompson RCA, Lymbery AJ, Smith A, Morris K, Wayne A et al. (2010) Non-archetypal *Toxoplasma gondii* genotypes in Western Australian wildlife species. Paper presented at the XIIth International Congress of Parasitology: Melbourne, Australia, 15-20th August 2010 (ABSTRACT).
208. Parkar U, Traub RJ, Hijjawi N, Wayne A, Morris K, Thompson RCA (2010) The development of a molecular-based multiplex method to detect *Blastocystis*, *Cryptosporidium* sp and *Giardia duodenalis*. Paper presented at the XIIth International Congress of Parasitology: Melbourne, Australia, 15-20th August 2010 (ABSTRACT). p. 1.
209. Parnell JAN, Womersley HBS, Sinkora D, Vaughan A, Huisman JM (2010) W.H. Harvey's Australian travelling sets of algae in the Herbarium of Trinity College Dublin (TCD) and the National Herbarium of Victoria (MEL), Australia. *Biology and Environment: Proceedings of the Royal Irish Academy* **110B**, 119-161.
210. Parsons BC, Gosper CR (2011) Contemporary fire regimes in a fragmented and an unfragmented landscape: implications for vegetation structure and persistence of the fire-sensitive malleefowl. *International Journal of Wildland Fire* **20**, 184-194.
211. Peacock D, Abbott I (2010) The mongoose in Australia: failed introduction of a biological control agent. *Australian Journal of Zoology* **58**, 205-227.
212. Pearson D (2010) *Snakes of Western Australia*. Department of Environment and Conservation, Western Australia, Bush Books Department of Environment and Conservation, Kensington, Western Australia. 72 pp.
213. Pennifold M, Pinder A (2011) South-west forest stream biodiversity monitoring: Forest management plan 2004-2013, key performance indicator 20: interim report. Department of Environment and Conservation, Woodvale, Western Australia. 207 pp.
214. Pinder A (2010) Leeches: our poorly known invertebrates. *Bushland News* **74**, p. 5.
215. Pinder A (2010) Non-marine aquatic invertebrates: challenges and case studies (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species* p. 24.
216. Pinder A, Cale D, Leung A (2011) Aquatic invertebrate diversity in Drummond natural diversity recovery catchment wetlands, 2004-2010. Department of Environment and Conservation, Woodvale, Western Australia. 12 pp.

217. Pinder A, Cale D, Leung A, Halse S (2010) Waterbird and invertebrate monitoring of the Warden and Gore wetlands in November 2009 and February 2010. Department of Environment and Conservation, Woodvale, Western Australia. 54 pp.
218. Pinder AM, Halse SA, Shiel RJ, McRae JM (2010) An arid zone awash with diversity: patterns in the distribution of aquatic invertebrates in the Pilbara region of Western Australia. *Records of the Western Australian Museum. Supplement* **78**, 205-246.
219. Pinder A, Leung A (2010) Report on the October 2008 sampling of the aquatic invertebrate assemblages of mound springs of the Three Springs area threatened ecological community. Department of Environment and Conservation, Woodvale, Western Australia. 21 pp.
220. Pryor LD, McCaw WL, Grierson PF, Murphy BP, Bowman DMJS (2011) Population structures of the widespread Australian conifer (*Callitris collumellaris*) are a bio-indicator of continental environmental change. *Forest Ecology and Management* **262**, 252-262.
221. Quinn J, Robley A, Johnston M, Algar D (2010) Feral cats: monitoring and control. *Supervising Scientist, Australia, Internal Report* **568**, 81-85.
222. Radford IJ (2010) Fire regimes and regional biodiversity declines in north-west Australian tropical savannas? Review of knowledge and recommendations for future research. *Conservation Science Western Australia* **7**, 469-479.
223. Rea AJ, Jung T, Burgess TI, Stukely MJC, Hardy GE St J (2010) *Phytophthora elongata* sp. nov. a novel pathogen from the *Eucalyptus marginata* forest of Western Australia. *Australasian Plant Pathology* **39**, 477-491.
224. Reiss A, Wayne A, Pacioni C, Nicholls P, Eden P, Thompson A et al. [Smith A] (2010) The decline of the woylie (*Bettongia pencillata*) in Western Australia: an update on the investigation. Paper presented at the Australian College of Veterinary Scientists, Scientific Meeting, Surfers Paradise, Queensland, July 2010 (ABSTRACT). p. 1.
225. Robinson R (2010) *Amanita muscaria* in Western Australia. *Fungimap Newsletter* **41**, p. 13.
226. Robinson R (2010) Detection, recognition and management options for *Armillaria* root disease in urban environments. Paper presented at the International Society of Arboriculture Australia Chapter National Conference, 14-19 May 2010, Adelaide, South Australia. 1-5. Department of Environment and Conservation, Manjimup.
227. Robinson R (2010) First record of *Amanita muscaria* in Western Australia. *Australasian Mycologist* **29**, 4-6.
228. Robinson R (2011) Recognising the symptoms of *Armillaria* root disease. Department of Environment and Conservation, Kensington, Western Australia. 12 pp.
229. Robinson R, Tunsell V (comps) (2011) ForestCheck: report of progress, 2009-10. 120 pp.
230. Robinson RM, Williams M, Mellican A, Smith RH (2010) Monitoring the effects of logging on macrofungi in jarrah (*Eucalyptus marginata*) forest: results from the first five years of the FORESTCHECK project (ABSTRACT). In *ASM 2010 Sydney: program and abstract book: 2010 annual scientific meeting and exhibition of the Australian Society of Microbiology, 4-8 July 2010, Sydney Convention & Exhibition Centre NSW* p. 61.
231. Roy R, Kumar B, Moskvitin AS, Benetti S, Fatkhullin TA, Kumar B et al. [Martin R] (2011) SN 2008gz: most likely a normal type IIP event. *Monthly Notices of the Royal Astronomical Society* **414**, 167-183.
232. Rye B (2010) A lectotype and new combination in *Hypocalymma* (Myrtaceae: Chamelaucieae). *Nuytsia* **20**, 323-326.
233. Rye BL (2010) A revision of the *Micromyrtus racemosa* complex (Myrtaceae: Chamelaucieae) of south-western Australia. *Nuytsia* **20**, 37-56.
234. Sampson JF, Byrne M (2010) Characterizing the radiation of subspecies of polyploid *Atriplex nummularia* Lindl. (Chenopodiaceae) using microsatellite markers (ABSTRACT). In *Genetics Society of AustralAsia 2010: Annual Conference, Canberra 4-8 July: Programme and Abstracts*,. 9-10.
235. Shearer BL, Crane CE, Cochrane JA (2010) Prioritisation of *Lambertia* taxa for conservation according to the threat posed by *Phytophthora cinnamomi* (ABSTRACT). In *Threatened Species*

Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species 26-27.
236. Shearer BL, Crane CE, Cochrane JA (2010) Variation in susceptibility to *Phytophthora cinnamomi* infection within the genus *Lambertia*. *Australian Journal of Botany* **58**, 575-585.
237. Shearer BL, Crane CE (2011) Habitat suitability of soils from a topographic gradient across the Fitzgerald River National Park for invasion by *Phytophthora cinnamomi*. *Australasian Plant Pathology* **40**, 168-179.
238. Sinclair EA, Barrett RL (2010) Molecular markers provide an independent test of species boundaries in the two morphologically similar species *Desmocladus flexuosus* and *D. asper* (Restionaceae). *Nuytsia* **20**, 7-17.
239. Smith A, Morris K (2010) Fauna translocations to the mainland and offshore islands of Western Australia: Barrow Island and beyond (ABSTRACT). *Australian Mammal Society Newsletter* **Oct**, p. 31.
240. Sokoloff DD, Remizowa MV, Linder HP, Macfarlane T, Rudall PJ (2010) Arrangement of reproductive units in *Centrolepis* (Centrolepidaceae: Poales): cincinnus or spikelet? In *Diversity, Phylogeny and Evolution in the Monocotyledons* (eds A Barfod, JI Davis, G Petersen et al.), 425-436. Aarhus University Press, Aarhus, Denmark.
241. Stead-Richardson J, Bradshaw D, Friend T, Fletcher T (2010) Monitoring reproduction in the critically endangered marsupial, Gilbert's potoroo (*Potorous gilbertii*): preliminary analysis of faecal oestradiol-17[beta], cortisol and progestagens. *General and Comparative Endocrinology* **165**, 155-162.
242. Stone LM, Byrne M (2011) Comparing the outputs of five weed risk assessment models implemented in Australia: are there consistencies across models? *Plant Protection Quarterly* **26**, 29-35.
243. Stukely M, Webster J, Ciampini J (2010) Vegetation Health Service: annual report, 2009-2010, *Phytophthora* detection. Department of Environment and Conservation, Kensington, Western Australia. 16 pp.
244. Thiele KR (2010) *Darwinia hortiorum* (Myrtaceae: Chamelaucieae), a new species from the Darling Range, Western Australia. *Nuytsia* **20**, 277-281.
245. Thiele K (ed) (2010) *Nuytsia*. Volume 20, 2010. Department of Environment and Conservation, Kensington, Western Australia. 328 pp.
246. Thiele K (ed) (2011) *Nuytsia*. Volume 21(1), pages 1-34, 2011. Department of Environment and Conservation, Kensington, Western Australia. 34 pp.
247. Thiele KR (2011) Removal of the informal name *Epiblema grandiflorum* var. *cyaneum* ms from the Census of Western Australian Plants. *Nuytsia* **21**, 33-34.
248. Thiele K, Shepherd K, Chapman A (2010) Taxonomy for conservation: the role of taxonomic research in the conservation of rare and threatened flora in Western Australia (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species* p. 28.
249. Thomas N, Macmahon B, Marlow N (2010) Camera traps: paparazzi in the bush. *LANDSCOPE* **26(2)**, 27-31.
250. Thompson WA, Allen J, Jasper R (2010) Flora of select areas of three greenstone belts in the Yilgarn Craton: Bullfinch, Forrestania and Ravensthorpe. Department of Environment and Conservation, Woodvale, Western Australia. 275 pp.
251. Trudgen ME, Rye BL (2010) *Enekbatus*, a new Western Australian genus of Myrtaceae with a multi-locular indehiscent fruit. *Nuytsia* **20**, 229-259.
252. Veilleux HD, van Herwerden L, Evans RD, Travers MJ, Newman SJ (2011) Strong genetic subdivision generates high genetic variability among eastern and Western Australian populations of *Lutjanus carponotatus* (Richardson). *Fisheries Research* **108**, 74-80.
253. Volschenk ES, Burbidge AH, Durrant BJ, Harvey MS (2010) Spatial distribution patterns of scorpions (Scorpiones) in the arid Pilbara region of Western Australia. *Records of the Western Australian Museum. Supplement* **78**, 271-284.
254. Ward B, Burrows N, Lethbridge M (2010) Inland invaders: a million wild camels. *LANDSCOPE* **26(1)**, 40-44.
255. Waters C, Melville G, Coates D, Virgona J, Young A, Hacker R (2011) Variation in morphological traits among and within populations of *Austrodanthonia caespitosa* (Gaudich.) H.P. Linder and four related species. *Australian Journal of Botany* **59**, 324-335.

256. Wayne A, Marlow N, de Tores P (2010) Woylie (*Bettongia penicillata ogilbyi*): research for conservation (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species* p. 30.
257. Wayne A, Moore J (2011) The jewel in the crown: Perup and the upper Warren. *LANDSCOPE* **26(3)**, 10-17.
258. Wayne A, Ward C, Maxwell M, Vellios C (2010) Kingston project: responses of terrestrial vertebrates to timber harvesting in the jarrah forest (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species,* 31.
259. Webala P, Craig MD, Law BS, Armstrong KN, Wayne AF, Bradley JS (2011) Bat habitat use in logged jarrah eucalypt forests of south-western Australia. *Journal of Applied Ecology* **48**, 398-406.
260. Webala PW, Craig MD, Law BS, Wayne AF, Bradley JS (2010) Roost site selection by southern forest bat, *Vespadelus regulus* and Gould's long-eared bat *Nyctophilus gouldi* in logged jarrah forests, south-western Australia. *Forest Ecology and Management* **260**, 1780-1790.
261. Wege JA (2010) *Stylidium* miscellany. 1, typifications and new taxa from south-west Western Australia. *Nuytsia* **20**, 79-108.
262. Wege J (2010) Targeted taxonomy: describing Western Australia's conservation-listed flora. Available at: http://www.dec.wa.gov.au/component/option,com_docman/task,doc_download/gid,4524/Itemid,/ Department of Environment and Conservation, Western Australia, Science Division, Information Sheet **34/2010**, Kensington, Western Australia. 2 p.
263. Whitford K (2010) Seed production in jarrah forest. Available at: http://www.dec.wa.gov.au/component/option,com_docman/task,doc_download/gid,4816/Itemid,/ Department of Environment and Conservation, Western Australia, Science Division, Information Sheet **42/2010**, Kensington, Western Australia. 2 pp.
264. Whitford K, Manning L, Wills A (2010) Wandoo crown condition 2010: report of five years of wandoo crown decline surveys. Available at: http://www.dec.wa.gov.au/component/option,com_docman/task,doc_details/gid,5008/Itemid,1628/ Department of Environment and Conservation, Kensington, Western Australia. 19 pp.
265. Wilkins CF, Chappill JA, Henderson GR (2010) An account of *Eutaxia* (Leguminosae: Mirbelieae) with a focus on the Western Australian species. *Nuytsia* **20**, 109-167.
266. Willers N, Bencini R, Mawson P, Morris K (2010) Population dynamics in the black-flanked rock-wallaby in the central wheatbelt of Western Australia (POSTER ABSTRACT). *Australian Mammal Society Newsletter* **Oct**, 73-74.
267. Williams AAE, Williams EP (2010) Field observations and photographs of some Tasmanian butterflies. *Western Australian Insect Study Society Newsletter* **Dec**, 7-8.
268. Williams MR (2011) Habitat resources, remnant vegetation condition and area determine distribution patterns and abundance of butterflies and day-flying moths in a fragmented urban landscape, south-west Western Australia. *Journal of Insect Conservation* **15**, 37-54.
269. Wills A, Hooper R (2011) Decline and recovery of wandoo crowns involving the beetle *Cisseis fascigera* (Buprestidae) (POSTER). Department of Environment and Conservation, Kensington, Western Australia. 1 poster.
270. Wilson SK, Depczynski M, Fisher R, Holmes TH, O'Leary RA, Tinkler P (2010) Habitat associations of juvenile fish at Ningaloo Reef, Western Australia: the importance of coral and algae. *PLoS One* **5**, e15185, 1-8.
271. Wilson S, Holmes T (2011) Reef fish and corals: unlocking the secrets. *LANDSCOPE* **26(3)**, 18-22.
272. Wittkuhn RS (2010) Wind-aided seed dispersal of perennial veld grass (*Ehrharta calycina*): implications for restoration in weedy urban bushland remnants. *Ecological Management and Restoration* **11**, 148-150.
273. Wittkuhn RS, Hamilton T (2010) Using fire history data to map temporal sequences of fire return intervals and seasons. *Fire Ecology* **6**, 97-114.
274. Wittkuhn R, McCaw L (2010) Fire intervals and biodiversity responses in the south-west of Western Australia. *Fire Note* Fire note **64**, Bushfire CRC, East Melbourne. 4 pp.
275. Wittkuhn RS, McCaw L, Wills AJ, Robinson R, Andersen AN, van Heurck P

et al. [Farr J, Liddelow G, Cranfield R] (2011) Variation in fire interval sequences has minimal effects on species richness and composition in fire-prone landscapes of south-west Western Australia. *Forest Ecology and Management* **261**, 965-978.
276. Wittkuhn RS, McCaw L, Wills AJ, Robinson R, Andersen AN, van Heurck P, Farr J, Liddelow G, Cranfield R, Burrows ND (2011) Resilience of open forests and shrublands to contrasting fire interval sequences in a Mediterranean environment of south-west Western Australia. In *Wildfire 2011: the 5th International Wildland Fire Conference, 9-13 May 2011, South Africa: Living with Fire: Addressing Global Change through Integrated Fire Management: Sun City, South Africa, 9-13 May 2011* pp. 1-11. Conference Organising Committee, Sun City.
277. Woinarski JCZ, Legge S, Fitzsimons JA, Traill BJ, Burbidge AA, Fisher A et al. [McKenzie NL, Radford I] (2011) The disappearing mammal fauna of northern Australia: context, cause, and response. *Conservation Letters* **4**, 192-201.
278. Yates C, Barrett S, Byrne M, Coates D, Gibson N, Ladd P (2010) Managing south-western Australia's threatened species in an era of global change (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species* p. 32.
279. Yates C, Byrne M, Gibson N (2010) Long-term viability of locally restricted species in a threatened ecological community. Available at: http://www.dec.wa.gov.au/component/option,com_docman/task,doc_download/gid,4523/Itemid,/ Department of Environment and Conservation, Western Australia, Science Division, Information Sheet **35/2010**, Kensington, Western Australia. 2 pp.
280. Yates C, Elith J, Gibson L, McNeill A, Midgley G, de Tores P et al. [Wayne A] (2010) The potential impacts of climate change and land transformation on biodiversity in Mediterranean climate south-west Western Australia: implications for threatened species conservation (ABSTRACT). In *Threatened Species Research Forum: Western Australian Ecology Centre, 9th July 2010: a Review of Western Australian Government Research into Threatened Species* 31-32.
281. Yates C, Ladd P, Coates D (2010) Life on the rocks: a cracking good place to live. *Western Wildlife: Newsletter of the Land for Wildlife Scheme* **14(3)**, 6-7.
282. Yeatman G, Mills H, Page M, Wayne A (2010) Demographic changes of a woylie (*Bettongia penicillata*) population with increasing density in a fenced reserve. Paper presented at the Australasian Wildlife Management Society Annual Conference, Torquay, Victoria, 1-3 December 2010 (ABSTRACT). p. 1.
283. Zosky K, Bryant K, Calver M, Wayne A (2010) Do preservation methods affect the identification of dietary components from faecal samples? A case study using a mycophagous marsupial. *Australian Mammalogy* **32**, 173-176.
284. Zub M, Cassan A, Heyrovský D, Fouqué P, Stempels HC, Albrow MD et al. [Martin R, Williams A] (2011) Limb-darkening measurements for a cool red giant in microlensing event OGLE 2004-BLG-482. *Astronomy and Astrophysics* **525**, A15,1-12.

CURRENT COLLABORATION WITH ACADEMIA
(Student Projects)

DEC Officer	Student	Project Title	Degree /level	Duration (yr – yr)	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	2005–2011	Prof J Majer	Curtin University
Algar, David	K Koch	Genetic diversity and phylogeography of Australian cats	PhD	2009–2011	Dr K Schwenk	Johan Wolfgang Gothe University
Burbidge, Allan	R Scott	Can vocal recognition be used to discern population spatial structure and dispersal in Carnaby's cockatoo?	MSc	2010–2012	Dr R Davis	Edith Cowan University
Burrows, Neil	J Fissioli	Predicting the distribution of tingle associations in south-west Australia	PhD	2005–2011	Dr G Wardell-Johnson	University of Queensland
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 Australian sandalwood	PhD	2010–2012	Dr J Plummer, Dr L Barbour	The University of Western Australia
Byrne, Margaret	V Stylianou	Morphological and 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
Byrne, Margaret; Coates, David	H Nistelberger	Ancient, terrestrial islands in a semi-arid landscape: patterns of genetic diversity in regional endemics of the Yilgarn banded iron formations	PhD	2010–2013	Dr D Roberts	The University of Western Australia
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

DEC Officer	Student	Project Title	Degree /level	Duration (yr – yr)	University Academic	University
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	F Zewe	Fox and cat interactions at western ringtail possum translocation sites	PhD	2011–2014	Assoc Prof R Bencini	The University of Western Australia
de Tores, Paul	G Bryant	The ecology and thermal biology of the south-west carpet python *Morelia spilota imbricata* in fox-controlled and uncontrolled areas of the Swan Coastal Plain and northern jarrah forest of Western Australia	PhD	2006–2010	Dr T Fleming, Dr K Warren	Murdoch 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	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
de Tores, Paul	L Zimmermann	Population density estimate of western ringtail possums at Karakamia Wildlife Sanctuary	Hons	2010	Asst Prof H Mills	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; 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
Farr, Janet	K Ironside	Trophic dynamics of predatory invertebrates in jarrah forests of differing fire history	MSc	2006–2011	Dr J Prince, Dr P Grierson	The University of Western Australia
Friend, Tony	J Austen	Trypanosomes of some Western Australian mammals: phylogenetics and ecology	PhD	2006–2011	Dr U Ryan	Murdoch University
Friend, Tony	J Pridham	Finding a dietary surrogate for Gilbert's potoroo (*Potorous gilbertii*)	Hons	2009–2010	Dr G Luck	Charles Sturt University
Huisman, John	F Hart	Systematics and pest potential of *Codium* (Chlorophyta) in Western Australia	Hons	2010	Dr J Huisman	Murdoch University
Huisman, John	R Dixon	Systematics of *Sargassum* (Phaeophyceae) in	PhD	2008–2010	Dr J Huisman	Murdoch University

DEC Officer	Student	Project Title	Degree /level	Duration (yr – yr)	University Academic	University
		Australia				
Kendrick, Alan; Rule, Mike	Various	Marine and Coastal Management Course	3rd yr	2010	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
McCaw, Lachie	A O'Donnell	Fire patterns and vegetation structure in semi-arid woodlands and shrublands in southern Western Australia	PhD	2006–2010	Dr P Grierson, Dr M Boer	The University of Western Australia
McCaw, Lachie	J Cargill	Fate of *Eucalyptus marginata* seed from canopy store to emergence in the northern jarrah forests of Western Australia	PhD	2006–2010	Prof W Stock, Dr E van Etten	Edith Cowan University
McCaw, Lachie	J Hollis	Coarse woody fuel availability and consumption in Australian forests fires	PhD	2007–2010	Dr W Anderson, Dr J Chapman, Dr P Ellis, Dr S Matthews	University of New South Wales
McCaw, Lachie	M Peace	Fire weather	MSc	2010–2012	Dr T Mattner, Dr G Mills,	Adelaide University, Centre for Australian Weather and Climate Research
Millar, Melissa	A Williams	Are banded iron formations refugia for two Western Australian acacia species?	Hons	2011	Dr S Krauss	The University of Western Australia
Moody, Michael	J Stingemore	The effect of plant density on dispersal mechanisms and genetic variation for two co-occurring *Persoonia* species	PhD	2009–2011	Asst Prof M Moody	The University of Western Australia
Moody, Michael	S Battilana	Molecular systematics and phylogeography of the *Myriophyllum callitrichoides* complex in the Kimberley Region	Hons	2010	Asst Prof M Moody	The University of Western Australia
Moody, Michael	T Hevroy	Molecular taxonomy, phylogeography and population genetics of the *Grevillea thelemanniana* complex	PhD	2010–2012	Asst Prof M Moody	The University of Western Australia
Moody, Michael; Poot, Pieter	Y Smythe	Determining population health, viability and resilience to natural threats in the DRF *Banksia verticillata*	Hons	2010	Asst Prof M Moody, Asst Prof P Poot	The University of Western Australia
Morris, Keith	J Dunlop	Factors affecting fauna translocation success.	PhD	2010–2012	Prof A Thompson	Murdoch University
Morris, Keith	K Bettink	Ecology and taxonomic differentiation in the	MSc	2010–2011	Dr H Mills	The University of

DEC Officer	Student	Project Title	Degree /level	Duration (yr – yr)	University Academic	University
		Australian water rat and implications for its conservation status in Western Australia.				Western Australia
Morris, Keith	N Willers	The use of the contraceptive deslorelin to manage overabundant rock-wallaby populations	PhD	2007–2010	Assoc Prof R Bencini	The University of Western Australia
Pinder, Adrian	B Clark	Determining the potential of habitat restoration to increase taxonomic diversity and presence of functional feeding groups in stream macroinvertebrate communities	Hons	2011	Dr A Storey	The University of Western Australia
Pinder, Adrian	N McLure	An investigation of the factors influencing the composition and structure of aquatic invertebrate communities at Lake MacLeod, Western Australia	Hons	2011	Dr P Horwitz	Edith Cowan University
Poot, Pieter; Moody, Michael	M Hocking	Habitat characteristics that affect survival and growth of two translocated threatened flora species, *Acacia awestoniana* and *Banksia ionthocarpa* subsp. *ionthocarpa* in South Western Australia	Hons	2011	Asst Prof P Poot, Asst Prof M Moody	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
Prince, Bob	L Woolgar	Where are male loggerhead turtles produced in Western Australia? Current and future scenarios	Hons	2010–11	Dr N Mitchell	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	2006–2011	Dr T Burgess, Dr G St J Hardy	Murdoch University
Shearer, Bryan	L Eshraghi	Use of *Arabidopsis* as a model system to study mechanisms of action of phosphite	PhD	2008–2011	Dr G Hardy	Murdoch University
Shearer, Bryan	P Scott	Tuart decline	PhD	2004–2011	Dr G Hardy	Murdoch University
Shearer, Bryan	P Staskowski	Mechanisms of phosphite action	PhD	2006–2010	Dr G Hardy	Murdoch University

DEC Officer	Student	Project Title	Degree /level	Duration (yr – yr)	University Academic	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
Smith, Andrew	C Thomas	Trypanosomes of woylies from Western Australia: vector identification, in vitro cultivation and phylogenetic analysis.	PhD	2010–2013	Prof A Thompson	Murdoch University
Stukely, Mike	A Rea	Classical and molecular taxonomy and pathogenicity testing of *Phytophthora* species	PhD	2007–2011	Dr G Hardy	Murdoch University
Wayne, Adrian	A. Worth	The effect of *Toxoplasma* on woylie behaviour	PhD	2011–2013	Prof A Thompson	Murdoch University
Wayne, Adrian	C Pacioni	The population and epidemiological dynamics associated with recent decline of woylies (*Bettongia penicillata*) in Australia.	PhD	2006–2010	Prof I Robertson, Dr P Spencer, Dr K Warren	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	G Kaewmongkol	*Bartonella* infections in wildlife and domestic animals in Western Australia	PhD	2010–1212	Dr S Fenwick	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 Bain	Ecological study of the quokka (*Setonix brachyurus*) in the southern forests of south-west Western Australia	PhD	2006–2012	Assoc Prof R Bencini	The University of Western Australia
Wayne, Adrian	K Zosky (nee Rodda)	Resource availability and woylie declines in south-west Western Australia	PhD	2007–2011	Dr K Bryant, Dr M Calver	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	Y Abdad	Rickettsial infections in wildlife and humans in Western Australia	PhD	2006–2011	Dr S Fenwick	Murdoch University
Wayne, Adrian; Morris, Keith	S Pan	*Toxoplasma gondii* infection and atypical genotypes in Western Australian wildlife species.	PhD	2008–2011	Prof A Thompson	Murdoch University
Wayne, Adrian; Morris, Keith	U Parkar	Blasocystis and other protozoa in humans and wildlife	PhD	2006–2011	Prof A Thompson	Murdoch University

DEC Officer	Student	Project Title	Degree /level	Duration (yr – yr)	University Academic	University
Wayne, Adrian; Smith, Andrew; Morris, Keith	H Burmej	Ectoparasites of threatened mammals in Western Australia: biodiversity and impact	PhD	2007–2011	Prof A Thompson, Dr A Smith	Murdoch University
Wittkuhn, Roy	B Pekin	Influence of fire frequency and resource gradients on the structure and diversity of the jarrah (*Eucalyptus marginata* Donn ex Sm.) forest of south-west Australia	PhD	2006–2010	Dr P Grierson, Dr M Boer, Dr C Macfarlane	The University of Western Australia
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-west Australia	PhD	2010–2013	Dr N Enright	Murdoch University

EXTERNAL PARTNERSHIPS

Partnership Name i.e. CRC, Govt Depts, Universities, Industries, Other (sponsorships etc)	Project	External funding and source 2010/2011 ($)	DEC Involvement (in kind and $)
ANZEC/CRC for Australian Weed Management	Technical Group for weeds of conservation significance	Nil	G Keighery (0.05)
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 Queensland, The University of Western Australia	Broadening the spatio-temporal scope of ecological studies to anticipate change in Australian forested ecosystems	$120K for three years	N Burrows (0.05), B Ward (0.2), G Liddelow (0.2), R Cranfield (0.1), J Farr (0.1), A Wills (0.1), P Van Heurck (0.1), R Robinson (0.1), K Bain (0.05), D Green (0.05), T Middleton (0.05), L Shu (0.05)
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, The University of Western Australia	Fire management of complex rehabilitated forests—quantifying and understanding spatial variability of forest structure and fuels	$465K for three years	L McCaw (0.05)
Australasian Wildlife Conservancy, The University of Western Australia	Population density estimate of western ringtail possums (*Pseudocheirus occidentalis*) at Karakamia Wildlife Sanctuary	Nil (AWC) $2K (UWA)	P de Tores (0.1)
Australian Biological Resources Study (ABRS)	Bush Blitz: reserve surveys and tactical taxonomy	$8K for 2009/2010; $5K for 2010/2011	T Macfarlane (0.1)
Australian Biological Resources Study (ABRS) 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 (AIMS)	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), J Moore (0.3), K Murray (0.15), T Holmes (0.05), J Huisman (0.05)
Australian Institute of Marine Science, CSIRO Marine and Atmospheric Research, Department of Fisheries	2010/2011 Western Australian regional-scale coral bleaching study	Nil	J Moore (0.3), S Wilson (0.01)
Australian Marine Science Association (Western Australia)	Rottnest Young Scientist Workshop	Nil	T Holmes (0.01) $500 sponsorship

Partnership Name i.e. CRC, Govt Depts, Universities, Industries, Other (sponsorships etc)	Project	External funding and source 2010/2011 ($)	DEC Involvement (in kind and $)
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	Ecology and management of northern quoll in the Pilbara	$250K p.a. 3 years (2010–2012)	K Morris
BHP Billiton Iron Ore	Identification Botanist position at the Western Australian Herbarium	$105K	S Dillon (1.0)
BHP Billiton Iron Ore	SRE invertebrates in the Central Pilbara	$157K	B Durrant (0.3) DEC contribution of $20k
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 Johnson (0.3), B Muir (0.3)
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), A Smith (0.50), K Rusten (1.0), J Dunlop (1.0), E Miller (1.0), B Johnson 0.3), B Muir (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 Science	Fire and the Great Western Woodlands	$70K (2011 CSIRO)	C Yates (0.1), C Gosper (1.0)
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 Society, Environment Water Population and Communities, Murdoch University	The uptake of cat baits by non-target fauna in the south-west of Western Australia	$42K (2010)	K Morris (0.1), P de Tores (0.2)
Department of Fisheries	Resource condition monitoring of mangroves in Northwest Australia	Nil	K Friedman (0.02)

Partnership Name i.e. CRC, Govt Depts, Universities, Industries, Other (sponsorships etc)	Project	External funding and source 2010/2011 ($)	DEC Involvement (in kind and $)
DSE (Victoria) and Department of Society, Environment Water Population and Communities (DSEWPaC)	PAPP toxicosis and cat bait pellet development	$100K p.a. from DSEWPaC	D Algar (0.05)
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)
Future Farm Industries CRC	Biodiversity Program Project —Management of weed and genetic risk in perennial landuse systems	$322K for three years (2008–2011)	M Byrne (0.3), B Macdonald (0.2)
GCN (Gamma Ray Burst Communication Network), USA	Supernova search	Nil	R Martin (0.05)
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	Monitoring fish and coral communities at Trunk reef	$ 2K	S Wilson (0.05)
Karrara Mining Ltd	An assessment of population genetic variation and structure of *Acacia woodmaniorum*, and its phylogenetic relationship to other acacia species	$499K (2008–2011)	D Coates (0.1), M Millar (1.0)
Kimberley Land Council	Kimberley islands biological survey — indigenous liaison and participation	Nil	L Gibson (0.7), N McKenzie (0.3)
Kimberley Land Council	Movement behaviours and habitat usage of West Kimberley dugongs: A community based approach	$129 990 (Australian Marine Mammal Centre for two years 2009/2010, $30 000 Woodside Energy	S Wilson (0.05), D Holley (0.1) $5 500 in kind –vessel use
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)
Murdoch University	Epidemiology of marri canker	Nil	B Shearer (0.4)
Murdoch University	Macrophytes, macroalgae, phytoplankton and macroinvertebrates of Vasse-Wonnerup	$80K in 2009/2010	A Clarke (0.05)
Murdoch University	Monitoring management effectiveness: Monkey Mia dolphins	Nil	C Simpson DEC contribution $15k-$25k pa for six years

Partnership Name i.e. CRC, Govt Depts, Universities, Industries, Other (sponsorships etc)	Project	External funding and source 2010/2011 ($)	DEC Involvement (in kind and $)
Murdoch University	Taxonomic studies of Western Australian marine plants	Murdoch University, $50K p.a. 2008–2010	J Huisman (0.5) $50k per annum 2008-2010
Murdoch University	Woylie Conservation research project	Nil	A Wayne (0.6), C Vellios (0.6), C Ward (0.6), M Maxwell (0.6)
Murdoch University (CPSM)	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 (CPSM)	Molecular investigation of *Phytophthora* hybrids	$5K p.a. (2009–2011)	M Stukely (0.05)
National Climate Change Adaptation Research Facility	Network case study: marine biodiversity and resources network	$900	T Holmes (0.03)
National Heritage Trust (Kimberley Land Council)	Kimberley islands biodiversity asset identification — Phase 1 (incl. indigenous liaison and participation)	$2.7m 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)
Perth Zoo	Numbat juvenile survival monitoring	$8.45K Wildlife Conservation Action (2009–2011)	T Friend (0.1)
Perth Zoo	Woylie Conservation research project	$10.5K Wildlife Conservation Action	A Wayne (0.6), C Vellios (0.6), C Ward (0.6), M Maxwell (0.6)
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	$23K	S van Leeuwen (0.01), N Guthrie (0.8)
Satterley Property Group	Factors associated with western ringtail possum (*Pseudocheirus occidentalis*) persistence within retained habitat at development sites	$400K 2009–2013	P de Tores (0.5)
SciTech Planetarium, UWA, STAWA	Astronomy education	Nil	A Williams (0.05)
SCNRM	Dibbler distribution and ecology in Fitzgerald River National Park	$28.1 in 2009/2010, Caring for Our Country	T Friend (0.05)
SCNRM	Gilbert's potoroo recovery program	$43.7 in 2009/2010, Caring for Our Country	T Friend (0.75), S Hill (1.0)
SCNRM	Numbat recovery program, South Coast	$43.7 in 2009/2010, Caring for Our Country	T Friend (0.05)

Partnership Name i.e. CRC, Govt Depts, Universities, Industries, Other (sponsorships etc)	Project	External funding and source 2010/2011 ($)	DEC Involvement (in kind and $)
SCNRM	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)
South Australian Dept Environment and Heritage	Woylie Conservation research project	Nil	A Wayne (0.6), C Vellios (0.6), C Ward (0.6), M Maxwell (0.6)
Space Telescope Science Institute, USA; Sth Afri 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 State NRM	D Coates (0.05), A Cochrane (0.05) DEC Regional Services (7.0)
State NRM	Urgent endangered flora recovery	$424 000 State NRM	0.05 D Coates DEC Regional Services (0.5)
Terrestrial Ecosystem Research Network (TERN)	Multiscale plot network, Ausplot SWATT	Nil	S van Leeuwen (0.05)
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	Imaging and CCD photometry of transient objects	Nil	R Martin (.05) A Williams (0.05), A Verveer (0.05)
The University of Western Australia	Mode of action of phosphonate in native hosts to *Phytophthora cinnamomi*	Ni	B Shearer (0.04)
The University of Western Australia	New tools to uncover a *Eucalyptus* phylogeny and evaluate conservation priority species	$28K — UWA Research Development Award	M Moody (0.2)
The University of Western Australia, SWCC, SCRIPT	Aboriginal landscape transformations in south-west Western Australia	ARC Linkage	N Burrows (0.01) DEC $6k for three years
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 —i nternet telescope	$1K	R Martin (0.01), A Verveer (0.05)
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

Partnership Name i.e. CRC, Govt Depts, Universities, Industries, Other (sponsorships etc)	Project	External funding and source 2010/2011 ($)	DEC Involvement (in kind and $)
University of Tasmania	Using tree rings of an Australian conifer as a bioindicator of decadal-scale environmental change	Nil	L McCaw (0.1)
Western Australian Naturalists' Club	PUBF: Perth urban bushland fungi project	$10K	N 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
Western Areas NL	Ecology of chuditch in the western woodlands	$38K	K Morris (0.1), B. Johnson (0.2)
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)
Western Australian Museum	Systematic revision of the endemic Australian scorpion genus *Urodacus* (Scorpiones, Urodacidae)	ABRS and WAM for three years	B Durrant (0.5) DEC contribution of $18k
Wheatbelt NRM	Terrestrial baselining of natural diversity data in Wheatbelt NRM Region	ACC funding	B Bayliss (0.5), P Gioia (0.05), J Harvey (0.5), A Rick (Consultant)
Woodside Energy	Taxonomic studies on Burrup flora	$120K	R Butcher (0.25), K Shepherd (0.25), J Wege (0.25)

Note: 1K = $1 000

SUMMARY of RESEARCH PROJECTS by REGIONS
(DEC, IBRA/IMCRA and NRM)

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
BIODIVERSITY AND CLIMATE CHANGE UNIT: COLIN YATES				
South Coast, Warren, Wheatbelt, Swan, Midwest	Avon Wheatbelt, Esperance Plains Geraldton Sandplains, Jarrah Forest, Mallee, Swan Coastal Plain, Warren	Avon, Northern Agricultural, South Coast, South West, Swan	Temperature thresholds for recruitment in south-west Western Australian flora	45
South Coast	Warren, Esperance Plains	South Coast	Comparison of plant canker disease 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, Swan, Midwest	Avon Wheatbelt, Esperance Plains, Geraldton Sandplains, Jarrah Forest, Mallee, Swan Coastal Plain, Warren	Avon, Northern Agricultural, South West, South Coast, Swan	Collaborative research on biodiversity and climate change in megadiverse ecosystems	47
Midwest	Geraldton Sandplains	Northern Agricultural	Climate change risks for biodiversity and ecosystem function in species-rich shrublands	48
South Coast, Warren, Wheatbelt	Avon Wheatbelt, Esperance Plains, Jarrah Forest, Mallee, Warren	Avon, South Coast, South West	Protecting the safe havens: will granite outcrop environments serve as refuges for flora threatened by anthropogenic climate change?	49
BIOGEOGRAPHY PROGRAM: STEPHEN VAN LEEUWEN				
Pilbara	Pilbara	Rangelands	Pilbara regional biological survey	50
Kimberley	Victoria Bonaparte, North Kimberley, Dampierland	Rangelands	Kimberley islands biological survey	51
Goldfields, Midwest	Avon Wheatbelt, Coolgardie, Murchison, Gascoyne, Yalgoo	Rangelands, Northern Agricultural	Floristic surveys of the banded iron formation (BIF) and greenstone ranges of the Yilgarn	52
South Coast	Esperance Plains, Mallee	South Coast	Biological survey of the Ravensthorpe Range	53
Swan, South West	Swan Coastal Plain	Swan, South West	Floristic survey of the remnant heaths and woodlands of the Swan Coastal Plain	53
All	All	All	Ecomorphological clues to community structure, bat echolocation studies	54
Pilbara	Pilbara	Rangelands	Short range endemism of ground-dwelling invertebrates in the central Pilbara	55
All	All	All	Development of ethically acceptable techniques for invertebrate wet-pit	56

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
			trapping	
Midwest, Goldfields	Murchison	Rangelands	Northern Goldfields Calcrete Survey — Phase 1	57
FAUNA CONSERVATION PROGRAM: KEITH MORRIS				
Midwest, Goldfields	Carnarvon, Gascoyne, Murchison, Gibson Desert	Rangelands	Development of effective broadscale aerial baiting strategies for the control of feral cats	58
Midwest	Avon Wheatbelt, Yalgoo	Northern Agricultural, Rangelands	Sustained introduced predator control in the Rangelands	59
South Coast, Warren	Esperance Plains, Jarrah Forest, Warren	South Coast, South West	Conservation of south coast threatened birds	59
Swan, South West	Swan Coastal Plain	South West	Translocation outcomes and monitoring of naturally occurring populations of the western ringtail possum, *Pseudocheirus occidentalis*	60
Swan, South West	Jarrah Forest	South West, Swan, Avon	The importance of fox, cat and native predator interactions to sustained fauna recovery in the northern jarrah forest — is there a mesopredator release effect?	61
Swan, South Coast, Wheatbelt, Warren	Avon Wheatbelt, Jarrah Forest, Mallee, Swan Coastal Plain, Warren, Yalgoo	South West, Swan, Avon, South Coast	Factors affecting establishment in the numbat (*Myrmecobius fasciatus*) recovery plan	62
Wheatbelt	Avon Wheatbelt	Avon	Feral cat control and numbat recovery in Dryandra woodland and other sites	63
Wheatbelt	Avon Wheatbelt	South West, Avon	An assessment of the effect of fox control on red-tailed phascogale (*Phascogale calura*) populations	64
Midwest, South Coast	Esperance Plains, Geraldton Sandplains, Jarrah Forest, Swan Coastal Plain	Northern Agricultural, South Coast	Dibbler (*Parantechinus apicalis*) recovery plan	65
South Coast	Jarrah Forest	South Coast	Gilbert's potoroo (*Potorous gilbertii*) recovery plan	66
Midwest	Carnarvon, Geraldton Sandplains	Rangelands, Avon	Genetics and ecology of the western barred bandicoot (*Perameles bougainville*)	67
Goldfields, South West, Wheatbelt, Warren	Avon Wheatbelt, Coolgardie, Jarrah Forest, Warren	Avon, South West, Rangelands	Probait trials: phase 2	68
Wheatbelt	Avon Wheatbelt	Avon, South West	Sustained fauna recovery in a fragmented landscape (Dryandra Woodland and Tutanning Nature Reserve)	68
Wheatbelt	Avon Wheatbelt	South West, Avon	Return to Dryandra	69
South Coast, Swan, South West, Warren, Wheatbelt	Avon Wheatbelt, Esperance Plains, Jarrah Forest, Mallee	South West, Swan, Avon, South Coast	Implementation of the recovery plan for the chuditch, *Dasyurus geoffroii*	70
Wheatbelt, Katanning work centre	Mallee	Avon Catchment	Factors affecting fauna recovery in the Wheatbelt—Lake Magenta and Dunn Rock nature reserves	71
Goldfields	Murchison, Gascoyne	Rangelands	Rangelands restoration—reintroduction of native mammals to Lorna Glen (Matuwa)	72
Pilbara	Pilbara	Rangelands	Barrow Island fauna translocations	73

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
Midwest	Swan Coastal Plain	Northern Agricultural	Ecology and conservation of threatened pythons in Western Australia	74
Midwest	Swan Coastal Plain	Northern Agricultural	Implementation of the Lancelin Island skink recovery plan	75
All except South West	All	State wide	Improving rock-wallaby conservation and management	76
Kimberley	Northern Kimberley, Central Kimberley, Ord Victoria Plains, Victoria Bonaparte	Rangelands	Impact of cane toads on biodiversity in the Kimberley	76
Warren	Jarrah Forest	South West	Identifying the cause(s) of the recent declines of woylies in south-western Australia	77
Swan, Goldfields	Coolgardie, Swan Coastal Plain	Swan, Rangelands	Conservation of Western Australian butterflies	78
Swan, Goldfields	Coolgardie, Swan Coastal Plain	Swan, Rangelands	Conservation of the graceful sun-moth	79
FLORA CONSERVATION PROGRAM: DAVID COATES				
South Coast, Midwest, Swan, Wheatbelt, Goldfields	Avon Wheatbelt, Coolgardie, Esperance Plains, Geraldton Sandplains, Mallee, Murchison, Swan Coastal Plain, Yalgoo	Avon, Northern Agricultural, Rangelands, South Coast, South West, Swan	Genetics and biosystematics for the conservation, circumscription and management of the Western Australian flora	81
Wheatbelt	Avon Wheatbelt, Swan Coastal Plain	Avon, Northern Agricultural, South Coast, Swan	Genetic and ecological viability of plant populations in remnant vegetation	82
Wheatbelt, Midwest, Swan, South West, South Coast, Warren	Avon Wheatbelt, Esperance Plains, Jarrah Forest, Mallee, Swan Coastal Plain,	Avon, 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	84
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	85
All	Avon Wheatbelt, Carnarvon, Coolgardie, Esperance Plains, Gascoyne, Geraldton Sandplains, Great Sandy Desert, Hampton, Jarrah Forest, Mallee, Murchison, Nullabor, Swan Coastal Plain, Warren, Yalgoo	Avon, Northern Agricultural, Rangelands, South Coast, South West, Swan	Seed biology, seedbank dynamics and collection and storage of seed of rare and threatened Western Australian taxa	86
Midwest, South Coast, South West, Wheatbelt	Avon Wheatbelt, Coolgardie, Esperance Plains, Geraldton Sandplains, Jarrah Forest, Mallee, Swan Coastal Plain, Warren	Avon, Northern Agricultural, South Coast, South West, Swan	Translocation of critically endangered plants	87
South Coast	Warren, Esperance Plains	South Coast	Effects of pre-treatments, microhabitats and on-site management in the translocation success of threatened plant species: an ecophysiological approach	88
Midwest, Wheatbelt, South Coast, Swan, South West, Warren	Avon Wheatbelt, Esperance Plains, Jarrah Forest, Swan Coastal Plain, Warren	Avon, South Coast, South West, Swan	Ecophysiology of rare flora restricted to shallow-soil communities	89

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
Goldfields, Midwest, South West, South Coast, Swan, Wheatbelt	Avon Wheatbelt, Esperance Plains, Jarrah Forest	Avon, Northern Agricultural, Rangelands, South Coast, South West, Swan	The population ecology of critically endangered flora	90
Goldfields	Coolgardie	Rangelands	Causes of rarity in four *Tetratheca* taxa in the Goldfields ranges	90
South West, South Coast	Esperance Plains, Jarrah Forest, Swan Coastal Plain	Avon, South Coast, South West, Swan	An investigation of the epidemiology and use of novel phosphite application techniques in *Phytophthora cinnamomi* infestations in national parks of the south coast of Western Australia	91
South West, South Coast	Esperance Plains, Jarrah Forest, Swan Coastal Plain	Avon, South Coast, South West, Swan	Integrated strategies for the control of *Phytophthora cinnamomi* using phosphite	92
Midwest, Swan, Wheatbelt, South West, Warren, South Coast	Avon Wheatbelt, Esperance Plains, Geraldton Sandplains, Jarrah Forest, Swan Coastal Plain, Warren	Avon, South Coast, South West, Swan	Susceptibility of rare and endangered flora to *Phytophthora*	93
Swan, South West, Midwest, Wheatbelt, South Coast, Warren	Avon Wheatbelt, Esperance Plains, Geraldton Sandplains, Jarrah Forest, Swan Coastal Plain, Warren	Northern Agricultural, Swan, Avon, South West, South Coast, Rangelands	Mundulla Yellows disease in Western Australia	94
Midwest, Swan, South West, Warren, South Coast, Wheatbelt	Avon Wheatbelt, Esperance Plains, Geraldton Sandplains, Jarrah Forest, Swan Coastal Plain, Warren	Northern Agricultural, Swan, Avon, South West, South Coast	Vegetation Health Service	95
Wheatbelt, Midwest, Swan, South Coast	Avon Wheatbelt, Coolgardie, Esperance Plains, Geraldton Sandplains, Mallee, Swan Coastal Plain	Avon, Northern Agricultural, Rangelands, South Coast, South West, Swan	Taxonomic studies on native and naturalised plants of Western Australia arising from biological survey	96
Pilbara	Pilbara	Rangelands	Wattles of the Pilbara	97
All	All	Avon, Northern Agricultural, Rangelands, South Coast, South West, Swan	Conservation status and systematics of Western Australia *Acacia*	98
Pilbara, Midwest, Goldfields	Central Ranges, Coolgardie, Gascoyne, Gibson Desert, Great Victoria Desert, Little Sandy Desert, Murchison, Nullabor, Pilbara, Yalgoo	Rangelands	Understanding mulga	98
All	All	All	Australian wattle identification	99
Kimberley, Pilbara	Central Kimberley, Dampierland, Northern Kimberley, Ord-Victoria Plains, Victoria Bonaparte, Carnarvon, Central Ranges, Gascoyne, Gibson Desert, Great Sandy Desert, Gascoyne, Little Sandy Desert	Rangelands	Resolving the systematics and taxonomy of *Tephrosia* in Western Australia	100
All	All	All	Taxonomic review and conservation status of the members of the Myrtaceae tribe Chamelaucieae and miscellaneous other Western Australian plant groups	101
All	All	All	Taxonomic resolution and description of new plant species, particularly Priority Flora and those areas subject	102

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
			to mining interests in Western Australia	
All	All	All	Taxonomy of selected families including legumes, grasses and lilies	103
All	All	All	Taxonomic studies in selected families, including Asteraceae, Celastraceae Malvaceae, Proteaceae	104
All	All	All	Herbarium collections management	105
All	All	All	The Western Australian plant census and Australian Plant Census	107
All	All	All	The Western Australian Herbarium's specimen database	108
All	All	All	FloraBase — the Western Australian Flora	108
All	All	All	Biodiversity informatics at the Western Australian Herbarium	109
Kimberley, Pilbara, Swan, South West, Warren, South Coast	Central Kimberley, Dampierland, Esperance Plains, Gascoyne, Geraldton Sandplains, Jarrah Forest, Northern Kimberley, Swan Coastal Plain, Victoria Bonaparte, Warren	Rangelands, Northern Agriculture, Swan, South West, South Coast	Taxonomic review and floristic studies of the benthic marine algae of north-western Western Australian and floristic surveys of Western Australian marine benthic algae	110
Kimberley, Pilbara, Midwest, Swan, South West, Warren, South Coast	Central Kimberley, Dampierland, Esperance Plains, Geraldton Sandplains, Jarrah Forest, Northern Kimberley, Swan Coastal Plain, Victoria Bonaparte, Warren	Rangelands, Northern Agriculture, Swan, South West, South Coast	The Western Australian marine benthic algae online and an interactive key to the genera of Australian marine benthic algae	111
Swan	Swan Coastal Plain	Swan	Perth Urban Bushland Fungi (PBUF) Project	112
All	All	All	Improving the comprehensiveness, accuracy and availability of taxonomic data about Western Australia's fungi in DEC biological datasets and biodiversity collections	113
South Coast, South West, Swan, Warren, Wheatbelt	Avon Wheatbelt, Esperance Plains, Geraldton Sandplains, Jarrah Forest, Swan Coastal Plain, Warren	Northern Agricultural, Swan, South West, South Coast	Strategic taxonomic studies in families including Epacridaceae, Rafflesiaceae, Rhamnaceae and Violaceae	114
All	All	All	Development of interactive identification platforms and content	114
South Coast, South West, Warren, Wheatbelt	Avon Wheatbelt, Coolgardie, Esperance Plains, Jarrah Forest, Mallee.	Avon, South Coast, South West	Surveys, systematics and genetic diversity of granitic vernal pools flora	115
All	All	All	New tools to uncover a *Eucalyptus* phylogeny and evaluate conservation priority species	116
All	All	All	Systematics of the triggerplant genus *Stylidium*	117
All	All	All	Strategic taxonomic studies in families including Amaranthaceae and Fabaceae (*Ptilotus*, *Gomphrena* and *Swainsona*) and other plant groups	118

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
All	Avon Wheatbelt, Esperance Plains, Geraldton Sandplains, Jarrah Forest, Mallee, Swan Coastal Plain, Warren	All	Taxonomy of undescribed taxa in the Ericaceae subfamily Styphelioideae, with an emphasis on taxa of conservation concern	119
LANDSCAPE CONSERVATION PROGRAM: LACHIE MCCAW				
Warren, South West, Swan	Jarrah Forest, Warren	South West, Swan	FORESTCHECK—Integrated site-based monitoring of the effects of timber harvesting and silviculture in the jarrah forest	121
South West, Warren	Jarrah Forest	South West	Monitoring long-term effects of various fire regimes on species richness and composition of southern jarrah forest understorey	122
Goldfields	Gascoyne, Murchison	Rangelands	Project Rangelands Restoration: developing sustainable management systems for the conservation of biodiversity at the landscape scale in rangelands of the Murchison and Gascoyne bioregions — managing fire and introduced predators	122
Warren	Jarrah Forest	South West	Burning for biodiversity: Walpole fine grain mosaic burning trial	124
Goldfields, South Coast, Midwest, Wheatbelt, South West, Warren	Avon Wheatbelt, Coolgardie, Esperance Plains, Geraldton Sandplains, Jarrah Forest, Mallee, Murchison, Swan Coastal Plain	Avon, Northern Agricultural, Rangelands, South West, South Coast	Genetic analysis for the development of vegetation services and sustainable environmental management	125
South West, Warren	Jarrah Forest	Avon, South West	Identification of seed collection zones for rehabilitation	126
Midwest, Wheatbelt, South Coast	Avon Wheatbelt, Esperance Plains, Geraldton Sandplains	Avon, Northern Agricultural, South Coast	Management of environmental risk in perennial landuse systems	126
Midwest, South Coast, Wheatbelt, South West, Swan, Warren	Avon Wheatbelt, Esperance Plains, Geraldton Sandplains, Jarrah Forest, Mallee	Avon, Northern Agricultural, South West, South Coast	State Salinity Strategy wetland monitoring	128
South West, Swan, Warren	Jarrah Forest, Warren	Swan, South West, South Coast	Monitoring stream biodiversity (KPI 20 of Forest Management Plan)	129
Kimberley, Goldfields, Wheatbelt, Warren	Central Kimberley, Gascoyne, Jarrah Forest, Victoria Bonaparte	Avon, Rangelands, South West	Bushfire CRC Project B1.4: Improved methods for the assessment and prediction of grassland curing	129
Swan	Jarrah Forest	South West, Swan	Hydrological response to timber harvesting and associated silviculture in the intermediate rainfall zone of the jarrah forest	130
South West	Swan Coastal Plain	South West	Management of the Vasse-Wonnerup wetlands	131
Warren	Warren	South Coast, South West	Monitoring post-fire effects from the 2001 Nuyts wildfire	132
Warren	Jarrah Forest, Warren	South West	Long-term monitoring of timber harvesting on bird populations in south-west forest	133
South West, Swan, Warren	Jarrah Forest, Warren	South Coast, South West, Swan	Project Vesta—prediction of high intensity fire behaviour in dry eucalypt forest	133
Warren	Warren	South West	Increasing productivity of karri regrowth stands by thinning and	134

DEC Region	IBRA/IMCRA	NRM Region	Project Title	Page
			fertilising	
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Pilbara, Midwest, Swan	Ningaloo, Shark Bay, Central West Coast	Rangelands, Perth	Western Australian regional-scale coral bleaching study	165
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RESEARCH ACTIVITIES

BIODIVERSITY AND CLIMATE CHANGE UNIT

UNIT MANAGER: DR 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 (BCCU) 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 BCCU 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 (0.2).

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, our 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 Australian flora.
- Identify potentially 'at risk' plant species and incorporate this data in modelling impacts of climate change on 'at risk' species.
- Utilise these data as a basis for developing management response options including fire management and flora translocations.

Summary of progress (2010/2011) and main findings

- Scientific paper on germination and early seedling growth temperature thresholds for Stirling Range species accepted in *Austral Ecology* (online Dec 2010).

- Temperature profiling of seed from populations of *Banksia* species across a rainfall gradient has commenced.
- Temperature probes on Bluff Knoll continue to provide data on the relationship between soil and air temperatures. Data will continue to be logged to obtain comprehensive temperature data to direct germination studies.

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 12-18 months)

- Determine the influence of projected climate change on seed and seedling traits in species, population and range dynamics along an E-W climate gradient in Western Australia.
- Submit manuscript for publication on *Banksia* germination temperature thresholds and relationship between current climate envelopes.

Comparison of plant canker disease 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 (0.8), S Barrett (0.2), B Shearer (0.05), C Dunne (0.05).

Context

The contribution of canker fungi to stem and branch death in south-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 impact of canker pathogens in high-value natural and translocated Declared Rare Flora (DRF) populations including threatened ecological communities.
- Test for correlations of canker impact with climate variables.

Summary of progress (2010/2011) and main findings

- Baseline transects have been established across climatic gradients in the south-west of Western Australia providing capacity to quantify impact of climate change. Fifty two semi-permanent monitoring transects (20 with loggers measuring temperature, humidity and dew point) were established in communities of *B. baxteri, B. coccinea, B. verticillata* and translocation sites of *L. orbifolia* subsp. *orbifolia*.
- Three main canker causing pathogens were isolated and identified, and deposited in the Department of Agriculture Plant Pathogen collection. Five hundred and forty individual cankers were cultured, pathogens isolated and identified morphologically.
- Significant correlation of canker impact with basic climatic variables was identified.
- An increase in canker disease incidence and severity was identified by comparison of the initial assessment in March 2010 and the second assessment in November 2010.
- A prescription was developed for fungicide treatment to reduce rate of canker lesion development.

Management implications

- Preliminary recommendations are now available for fungicide treatments to reduce the rate of canker lesion development within the translocated proteaceous DRF 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 recovery plans at the species and community level.

Future directions (next 12-18 months)

- Determine influence of climate on incidence and severity of canker impact in proteaceous species in south-western Australia.
- Evaluation of fungicides for control of canker in proteaceous species of south-western Australia.
- Describe new genus and species of canker pathogen in Cryphonectriaceae in conjunction with Murdoch University.
- Repeat rating and subsequent analysis of transects in November 2011.
- Publication of three research papers.

Collaborative research on biodiversity and climate change in megadiverse ecosystems

SPP# to be allocated

Team members

C Yates (0.2). External Collaborators: G Midgley, South African National Biodiversity Institute; D Le Maitre, CSIR; D Richardson, University of Stellenbosch; J Scott, B Webber, CSIRO Climate Change Adaptation Flagship.

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 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 (2010/2011) and main findings

- Completed a study investigating the utility and robustness of different modelling paradigms for predicting the distributions of mutually exchanged Western Australian and South African plant species that have become invasive in their alien ranges.
- Manuscript “Modeling horses for novel climate courses: insights from projecting potential distributions of native and alien Australian acacias with correlative and mechanistic models” accepted for publication 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 12-18 months)

- Write up manuscript investigating *Watsonia* and *Anigozanthus* distributions in South Africa and Australia under the influence of climate change.
- 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# to be allocated

Team members

C Yates (0.2). External Collaborators: N Enright, Murdoch University; K Smettem The University of Western Australia; R Froend, Edith Cowan University; G Midgley, South African National Biodiversity Institute.

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 (2010/2011) and main findings

- Continued measurement of climate and soil moisture across the soil depth gradient on the Eneabba sandplain.
- Continued measurement of plant water use and demography in two woody plant guilds across the soil depth gradient.
- Established climate manipulation experiments.

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 12-18 months)

- Continue ecohydrology and demographic studies.
- Monitor climate manipulation experiments.

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

SPP# to be allocated

Team members

C Yates (0.2), M Byrne (0.1). External Collaborators: G Wardell-Johnson, L Mucina, Curtin University; K van Niel, The University of Western Australia; S Franklin, University of Saskatchewan; S Hopper, Royal Botanic Gardens Kew, AAMHatch.

Context

Many plant and animal species have survived previous climate change by contracting to dispersed refuges where local climate conditions ameliorate regional changes. Such refuges 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 refuges 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 (2010/2011) and main findings

- Established climate stations and microclimatic sensor arrays on five GOs.
- Established 150 vegetation plots across environmental gradients on five GOs.
- Commenced modelling of LiDAR and other multi-spectral remote sensed data for 28 GOs field sites.
- Commenced phylogeographic studies on two common GO endemic plant species *Kunzea pulchella* and *Stypandra glauca.*
- Continued databasing Hopper's GO species occurrence records.
- Reviewed manuscript "Refugia: identifying and understanding safe havens for biodiversity under climate change" accepted for publication in journal *Global Ecology and Biogeography*.

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 12-18 months)

- Continue measuring micro-climatic variation on five GOs.
- Continue modeling LiDAR and multi-spectral remote sensed data.
- Establish 300 vegetation plots across 10 GOs.
- Complete entry of Hopper's GO data and QA database.
- Commence study of plant phenology on GOs.
- Continue phylogeographic analysis and commence population genetic studies.

BIOGEOGRAPHY

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.

Pilbara regional biological survey

SPP# 2002-004; SPP# 2004-002

Team members

N McKenzie (0.6), N Guthrie (0.1), B Durrant (0.1), AH Burbidge (0.5), S van Leeuwen (0.2), M Lyons (0.4), A Pinder (0.25), M Langley (0.9), J Rolfe (0.4). External Collaborators: S Halse, P Doherty, M Harvey, R Johnstone, A Baynes, B Heterick, T Weir, D Blinn, N Gunawardene, E Volschenk.

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.

Aim

Provide a regional perspective on biodiversity and nature conservation priorities, provide data on the distribution of the biota, identify gradients in community composition and the environmental factors related to these gradients, and complement site-specific studies being undertaken by mining companies and others.

Summary of progress (2010/2011) and main findings

- All sampling and sorting completed.
- The first 11 papers are now published as a hard-cover book in the externally-refereed journal *Records of the Western Australian Museum* 78 (Part 1), including Introduction, small-ground mammals, bats, ants, beetles, spiders, aquatic invertebrates, birds, scorpions, original mammal fauna and weeds, along with a CD containing data-sets as Appendices.
- The reptile and frog paper is in review.
- Drafts of the original bird fauna, stygofauna, wetland aquatic flora and riparian flora papers are in preparation.
- Terrestrial flora identifications complete, and compilation of matrix commenced.
- Preparations for a conservation gap analysis of the now-compiled terrestrial zoology and aquatic biodiversity data sets has commenced.

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 will provide baseline information for long-term ecological monitoring of the region.

Future directions (next 12 months)

- Compile and analyse terrestrial flora matrices then draft and submit the flora paper for publication.
- Submit, referee and publish the seven remaining papers as hardcover volume 'Part 2'.
- Undertake road show to update Pilbara communities on survey findings and outputs.

Kimberley islands biological survey

SPP# 2007-001

Team members

L Gibson (0.7), F Köhler (1.0), R Palmer (1.0), M Lyons (0.3), G Keighery (0.15), N McKenzie (0.15), D Pearson (0.1), W Caton (1.0), P Handasyde (0.75), V Kessner (0.75), M Cowan (0.1), J Rolfe (0.1).

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 which are indicators of biogeographical patterning, and environmental health, and which provide a basis for condition monitoring of the targeted survey islands.

Aims

- Provide the knowledge base that will enable better decision making for conservation given the imminent arrival of the cane toad on the adjacent mainland and potentially on some of the islands.
- Inform development proposals by the resources and tourism industries and provide information for community-based natural resource management and biodiversity planning.

Summary of progress (2010/2011) and main findings

- Dry season survey completed on Mary Island and Wargul Wargul Island.
- Vertebrate, land snail and plant identifications complete for all islands sampled and species lists tabulated.
- The survey continued to reveal the presence of additional island populations of many vertebrates.
- Collections have added significantly to the known flora for the surveyed islands including those that have seen previous botanical collecting.
- Popular science article published describing diversity of land snails in the Kimberley in *LANDSCOPE*. A further article on Kimberley reptiles is to be published in the next issue.
- A fourth scientific paper published on taxonomic descriptions of land snails and a further paper submitted on non-camaenid land snails.
- Presentation on preliminary findings given at a meeting of Traditional Owners (Salt Water Country) in Broome.
- Presentations also given to the Western Australian Naturalists' Club and the Kimberley Society.
- A conference paper to be presented at Evolution 2011 Conference titled "A garbage gecko reveals fine-scale endemism in the monsoonal tropics of Australia" as a result of a collaboration.

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 12-18 months)

- Compile, analyse and interpret all data-sets.
- Complete and submit papers to Records of the West Australian Museum.
- Continue knowledge transfer activities.

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

SPP# 2007-005

Team members

N Gibson (0.5), W Thompson (0.25).

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 system 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.

Aim

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 (2010/2011) and main findings

- Paper on floristic patterns across four BIF ranges published.
- Last six papers on floristic patterns of BIF ranges in press with Conservation Science.
- Factsheets for 1 217 BIF quadrats and 134 BIF community types uploaded onto NatureMap.
- Three greenstone ranges papers currently being reviewed.
- Paper on meta analysis of the complete BIF dataset outlining extremely high beta diversity in the ranges and identified two hotspot of specialist BIF taxa currently being reviewed.
- Paper on overview of BIF surveys currently being reviewed.

Management implications

BIF and greenstone 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 12-18 months)

- Finalise publication of last six BIF papers.
- Proceed with publication of paper on meta analysis.
- Proceed with publication of paper on overview of BIF surveys.
- Proceed with publication of the three greenstone surveys for review and publication.
- Undertake further surveys on an additional three greenstone ranges.

Biological survey of the Ravensthorpe Range

SPP# 2007-006

Team members

N Gibson (0.1).

Context

The biodiversity values of the Ravensthorpe Range, an area of high prospectively 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 aim is to acquire additional knowledge on the floristics of the Ravensthorpe Range and 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.

Aim

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

Summary of progress (2010/2011) and main findings

- Factsheets for 267 quadrats and 21 community types uploaded onto NatureMap.
- Submitted paper on Ravensthorpe Range vegetation communities.
- Submitted paper on correlation between floristic communities and vegetation mapping.

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 12-18 months)

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

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

SPP# 1993-038

Team members

G Keighery (0.2). External Collaborator: 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 non-government organisations, local government authorities, statutory planning authorities and the Environmental Protection Authority.

Aim

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 (2010/2011) and main findings

- Expert working group report completed for the Whicher Range Floristic Study.
- Scientific paper on vascular flora of national parks on the Margaret Plateau and Leeuwin-Naturaliste Ridge published in *Conservation Science*.
- Report on vegetation and flora of Bunbury area commenced. All nature reserves in area have flora lists databased.
- Report on Barracca Nature Reserve drafted.

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 12-18 months)

- Complete report on vegetation and flora of Bunbury area.
- Continue to prepare and publish taxonomic, area and floristic papers.
- Conclude work on Dandaragan Plateau (if funded).
- Publish report on Barracca Nature Reserve.
- Contribute to DEC SCP south management plan.

Ecomorphological clues to community structure; bat echolocation studies

SPP# 1993-028

Team members

N McKenzie (0.1). External Collaborator: 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 (relate them to community structuring mechanisms and species' realised foraging niches).
- Investigate metapopulation, environmental factors, including disturbances and species' energetic requirements, controlling the occurrence and conservation vulnerabilities of bats.

Summary of progress (2010/2011) and main findings

- Assemblage analysis of Kimberley mainland bats completed to assess composition of communities. Data on their foraging strategies, microhabitat-use and airframe attributes compiled and analyses to reveal guild relationships, and echolocation call dictionary developed for Kimberley bats. Species from Kimberley island bat recordings identified and island fauna lists analysed to determine compositional relationships to habitat, journal paper being written.
- *LANDSCOPE* article on echolocation ecology of Pilbara bats published.
- Co-published Environment Australia working group report on the extinction of the Christmas Island Pipistrelle.
- Paper published on the disappearing mammal fauna of northern Australia: context, cause and response in *Conservation Letters.*

Management implications

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

Future directions (next 12-18 months)

- Finalise draft and submit paper on ecology of Kimberley bat communities, including their echolocation ecology and lists of bats on Kimberley islands.
- Publish paper on the status of non-volant mammals along a rainfall gradient in the south-west Kimberley in *Australian Mammalogy.*
- Publish paper on recent developments in studies of the community structure and foraging ecology of Western Australian bats in Royal Zoological Society—Australasian Bat Society book on Australian bats.
- Finalise and submit journal paper on characteristic flight speeds in Western Australian bats.

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

SPP# 2009-012

Team member

B Durrant (0.6).

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 over what distance and/or landscape characteristics significant barriers occur to dispersal of SRE taxa.

Summary of progress (2010/2011) and main findings

- All field sampling completed.
- Specimens being prepared for identification by taxonomic experts are 80% completed.
- Soil samples analysis completed.
- Photographs being collated and analysed for habitat assessment are 80% completed.

Management implications

The data and knowledge gained will be used by industry and regulators (DEC, OEPA) as part of the EIA 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 12–18 months)

- Complete identifications.
- Complete habitat analysis.
- Carry out analysis of data.
- Complete report to funding provider (BHPBIO) and submit manuscript(s) for publication in peer reviewed journal.

Development of ethically acceptable techniques for invertebrate wet-pit trapping

SPP# 2010-004

Team members

M Cowan (0.3). External Collaborators: D Harris, K Ho, T Oldfield, Western Australian Chem Centre.

Context

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

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

Aims

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

Summary of progress (2010/2011) and main findings

- Examination of suitable chemical solutions through the Western Australian Chem Centre was concluded.
- Approval was sought and given by the 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.
- The first field trial was completed at Kalbarri National Park in June. Captures from this trial are currently being sorted and an assessment of the condition of the material and any biases in captures will determine if trials are to continue at two other locations in spring 2011.

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 six months)

- Continue with background research and laboratory trials to achieve the stated chemistry and animal ethics goals.
- Present findings to DEC's AEC.
- Establish another two field trial sites and sample all three trial sites for an extended period.

- Identify and quantify invertebrate captures and vertebrate bycatch for evidence of non-random trapping success.
- 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 (1.0), W Caton (0.25), J Kalic (0.25), R Coppen (0.25), A Markey (0.1), N Gibson (0.05).

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.

Aim

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 (2010/2011) and main findings

- 135 quadrats sampled on eight calcrete palaeodrainage channels in 2010.
- A draft paper on the flora and vegetation of calcrete palaeodrainage channels prepared.
- A presentation delivered at the Kwongan Foundation 'Arid Zone Ecology' Workshop 2011.

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 non-government organisations in such assessments.

Future directions (next 12–18 months)

- Submit calcrete report for review.

FAUNA CONSERVATION

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.

Development of effective broadscale aerial baiting strategies for the control of feral cats

SPP# 2003-005

Team members

D Algar (0.9), N Hamilton (1.0), M Onus (1.0).

Context

Control of feral cats is one of the most important native fauna conservation issues in Australia. Development of an effective broadscale 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 are conducted when bait uptake is at its peak and therefore maximise efficiency.
- Examine baiting intensity (number of baits laid/km^2) 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 (2010/2011) and main findings

- Baiting trials at Lorna Glen have been completed and a manuscript documenting the results has been submitted for publication.
- A management plan for the control of cats on Christmas Island has been published and is being implemented.
- A data package has been submitted to Australian Pesticides and Veterinary Medicines Association for the registration of the feral cat bait.
- Two manuscripts documenting research findings were published.

Management implications

The development of baiting strategies that provide sustained and effective feral cat control enables extension of operational introduced predator control and wildlife reintroductions to the arid and semi-arid interior.

Future directions (next 12–18 months)

- Conduct further research to optimise the various parameters of baiting strategies, particularly on Dirk Hartog Island.

- Continue a comprehensive risk assessment of the potential impact of feral cat baiting programs on populations of non-target species in collaboration with the federal Department of Sustainability, Environment, Water, Population and Communitie and the Victorian Department of Sustainability and Environment, and where necessary, devise methods to reduce this risk.

Sustained introduced predator control in the rangelands

SPP# 2007-004

Team members

D Algar (0.1).

Context

The project will provide for the successful reconstruction and conservation of biodiversity as part of 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. This is a collaborative project involving DEC and Australian Wildlife Conservancy (AWC). The research was undertaken at AWC's Mt Gibson Sanctuary and at the nearby DEC acquired pastoral leases of Karara/Lochada. Mt Gibson Sanctuary is the treatment (baited) site and Karara/Lochada is the control or non-baited site, some 50km distant. Feral cat bait and baiting methodologies (i.e. timing of baiting, baiting intensity and frequency) are being employed to assess an integrated introduced predator (feral cat, fox and wild dog) control strategy. This strategy involves an annual baiting program, conducted in winter, with baits distributed at a density of 50 baits km^{-2}.

Aim

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

Summary of progress (2010/2011) and main findings

Draft final reports for the Invasive Animals CRC and DEC were prepared.

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 12–18 months)

Write papers to publish project results.

Conservation of south coast threatened birds

SPP# to be allocated

Team members

A Burbidge (0.3). 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. A high community involvement is maintained with over 40 volunteers per survey season. Community education and information assimilation is achieved through local and internationally focused media. Since western ground parrots are declining, this species is a high priority, but solutions will come from holistic management of the landscape as a whole.

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 (2010/2011) 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 the Critically Endangered western ground parrot.

Management implications

The project is providing a basis for decision-making and management actions for the recovery of threatened (and other) fauna, especially in respect of introduced predators and fire, in important conservation reserves on the south coast.

Future directions (next 12–18 months)

- Finalise writing up of data on response to fire by bristlebirds.
- Write up data on the status of the western ground parrots.
- Implement field-scale feral cat control (with monitoring) in key ground parrot habitat.
- Determine genetic relatedness of captive ground parrots and develop protocols for establishment of a captive breeding program for western ground parrots.
- Continue writing popular and scientific articles on fauna reconstruction on the south coast.

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

SPP# 2006-006

Team members

P de Tores (0.25). J Clarke, H Grimm, G Bryant, Murdoch University, K Yokochi, L Zimmerman, The University of Western Australia.

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 (non translocated) 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.

Aim

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

Summary of progress (2010/2011) 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.
- Results from distance sampling have shown previously relied upon *ad hoc* techniques used to estimate population size are unreliable.
- Genetic studies have revealed no evidence of historic or contemporary mixing of *in situ* (naturally occurring) populations separated by as little as 30km and with no physical barriers to dispersal or movement.
- Research has commenced on determining the factors associated with western ringtail possum persistence at retained habitat within development sites.

Management implications

- The findings from the limited genetic research to date has major implications for western ringtail possum conservation and for western ringtail possum translocation in particular, 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 which 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 12–18 months)

- Assessment of the conservation value of rope bridges and habitat patches retained within development sites.
- Assessment of fox and cat interactions at the translocation release sites at Leschenault Peninsula Conservation Park and Yalgorup National Park.

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 (0.25). G Bryant, Murdoch University, J Cruz, University of Queensland.

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 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 (2010/2011) and main findings

- Count data of fox and cat activity at sandplots were analysed using 'maximum likelihood' techniques and enabled abundance estimates, as opposed to indices of activity, to be derived for both species. The analysis 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 (either interference and/or exploitative completion) 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. This woylie population has persisted since translocated to the site during 'Operation Foxglove' in the period 1994–2000. In 2006 the previous 'Operation Foxglove' baiting regime was reinstated and the subsequent increase in woylie abundance occurred over a four year period when all other known woylie populations, outside fenced enclosures, were reported to decrease in abundance. The results provide strong evidence that predation by introduced predators is the primary cause for woylie decline.

Management implications

- Fox and cat control will need to be integrated through strategic control programs for both species.
- Broadscale 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 12–18 months)

- Complete all analyses.
- Provide a final report to DEC and the IA CRC.
- Submit manuscripts for publication.

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

SPP# 1993-145

Team members

T Friend (0.05).

Context

The numbat is Western Australia's state mammal emblem and in 2008 was elevated from Vulnerable to Endangered on the IUCN Red List. After a vigorous reintroduction campaign led by DEC, 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 lands.

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 (2010/2011) and main findings

- Monitoring of five established female numbats and their young at Cocanarup showed good survival and breeding in adult females but high mortality of young.
- Some previous conclusions on predation at Cocanarup have been overturned with new evidence—a putative goanna predation event (the first recorded) was shown to be a scavenging event, and chuditch have entered the picture, digging out a numbat burrow containing a female and young.
- Analysis of DNA from collars of predated animals has indicated that cats and foxes are both important predators of numbats at Dryandra.
- Top-up releases of four captive-bred and one Dryandra-born numbat from Perth Zoo were carried out at Boyagin and Batalling, but three were found predated (two taken by raptors and one dead with no sign of injury) and the other two signals were lost.
- The annual numbat abundance survey was carried out at Dryandra in November 2010. The results of this survey showed that, as in 2009, numbat numbers are lower than at any time since fox control commenced in 1983.
- A small group of the members of the Friends of the Fitzgerald River National Park community group have continued to monitoring radio-collared numbats and check the animals at Cocanarup between visits by DEC staff.

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 12–18 months)

This SPP will be completed in 2011/2012. Numbat recovery research and monitoring will continue under the new Dryandra feral cat control SPP.

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

SPP# to be allocated

Team members

T Friend (0.2), R Hill (1.0), B Macmahon (1.0).

Context

The Dryandra numbat population showed a strong positive response to fox (*Vulpes vulpes*) control during the 1980s and early 1990s, but then declined in 1993 and has since remained at low levels. Numbers have dropped even further over the last three years despite continued fox baiting. On two occasions, in 2008 and 2009, the remains of radio-collared numbats (two in each case) were found amongst other prey remains at cat dens in large hollow logs in the Dryandra woodland. A recent three-year study of causes of mortality within the woylie (*Bettongia penicillata*) population at Dryandra Woodland by Dr. Nicky Marlow revealed, from analysis of DNA swabbed from woylie carcases and radio-collars that about 60% of woylie deaths involved feral cats.

This project will investigate the effect of a cat baiting campaign using *Eradicat*® baits on rates of mortality amongst woylies and numbats at Dryandra woodland. It is essential that, in designing the baiting campaign to minimise the effect of baiting on non-target fauna, particular regard is given to species of conservation significance.

Aims

- Define the risks of using *Eradicat*® baits to non-target species in the Dryandra woodland, particularly to threatened species like the red-tailed phascogale (*Phascogale calura*).
- Implement cat control by baiting at Dryandra and measure the effect on numbat, woylie, cat and fox population numbers and on causes of death in numbats and woylies.

Summary of progress (2010/2011) and main findings

- Eleven numbats are currently radio-collared at Dryandra. They have been checked at least twice a week so that predation events can be quickly verified. No deaths have been recorded since the beginning of the project in January 2011.
- Twenty-seven woylies have been radio collared in Dryandra and seven at Boyagin Nature Reserve. There have been six woylie deaths so far and we are awaiting the results of analysis of predator DNA.
- Non-target bait uptake trails aimed at red-tailed phascogales and mardos (*Antechinus flavipes*) have been carried out using rhodamine B-dosed non-toxic *Eradicat*® baits. Red-tailed phascogales have an extremely low uptake rate (one out of 54 took bait) but three out of six mardos captured in baited areas had consumed some bait.

Management implications

This project has only been operating for seven months, but already the impact of cats on numbats and woylies is clear. Cat control is essential and should be implemented in such a way as to minimise the impact on non-target species.

Future directions (next 12–18 months)

- Daily monitoring of woylies and twice-weekly monitoring of numbats will continue in order to accumulate evidence on causes of death in both species.
- Further non-target baiting trials will be implemented, aimed at other species.
- Trapping on Western Shield traplines will continue to monitor woylie numbers and to capture animals for radio-collaring.
- Monitoring of known numbat populations will be continued by involving district staff and community members and handing over monitoring responsibility to district. Regular monitoring surveys will be essential in Dragon Rocks, Karroun Hill, and the northern jarrah forest east of Mundaring, Dryandra and Boyagin. Other areas will be included if possible.
- A survey for numbats and feral cats at Dragon Rocks is proposed in 2011/2012, with Great Southern District involvement. A survey for numbats will also be carried out at Karroun Hill Nature Reserve.

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

SPP# 1993-149

Team member

T Friend (0.05).

Context

The red-tailed phascogale is ranked Endangered on state, federal and IUCN threatened species lists, although a recent IUCN review recommended a downlisting to Vulnerable. This species is 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 region, and thus offers umbrella status as 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 (2010/2011) and main findings

- Trapping was carried out at all nine fox control research study sites. This will be the last census under the fox control assessment program. Numbers were surprisingly high given the extremely dry conditions over the previous year.
- Hair funnel surveys were carried out in likely red-tailed phascogale locations in the Fitzgerald River National Park under the auspices of the Integrated Predator Management Program 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 12–18 months)

- Results of the effects of fox control project to date will be written up.
- A recovery plan for the red-tailed phascogale will be completed involving community input. The plan recommends the continuation of this study and the strong involvement of landholders and local community members.

Dibbler (*Parantechinus apicalis*) recovery plan

SPP# 1995-011

Team members

T Friend (0.05), T Button (0.1).

Context

The *Dibbler Recovery Plan 2003–2013* identifies actions to improve the conservation status of this small marsupial, ranked endangered on state, federal and IUCN threatened species lists.

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, and
- Document and explain dibbler distribution in the Fitzgerald River National Park.

Summary of progress (2010/2011) and main findings

- The population study in the eastern Fitzgerald River National Park continued, with three monitoring sessions (September, December and April) at the study site. Numbers are still very low following the dry winters since 2008.
- No dibblers have been recorded at the Stirling Range National Park release site since November 2007, despite regular trapping sessions. A hair-trap survey was carried out from October to December 2010. No dibbler hairs were recovered. Regular trapping will be suspended.
- A new series of releases of dibblers commenced at the Peniup translocation site in October 2008, with the release of 40 dibblers from the Perth Zoo colony. This was followed by a release of 30 animals in October 2009 and 41 more in October 2010.

- Monitoring of the Peniup trapping grids in September 2010 resulted in the capture of 10 dibblers including young, indicating that breeding had occurred on-site. Trapping after the October release resulted in capture of 13 dibblers in November 2010 and of six in March 2010. This indicates an increase in the population over 2009 and another release is scheduled for October 2011.
- The Boullanger and Whitlock island populations were monitored in October 2010 and May 2011. Both trapping sessions indicate a dramatic decrease in dibbler numbers on both islands. This is most likely to be due to low rainfall over the last two winters. Rainfall data have been requested and an analysis of numbers versus rainfall will be carried out.

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.
- Large and intense wildfires diminish dibbler habitat.

Future directions (next 12–18 months)

- Monitoring of the Peniup translocation and the existing Fitzgerald River National Park and Jurien Bay island populations will continue.
- Building on the results of the 2008/2009 mouse baiting investigations, further rhodamine B trials to test improved bait tube designs will be carried out on the Jurien Bay islands.
- The study of dibbler distribution in the Fitzgerald River National Park will continue, with survey activity focused on spring-early summer period.

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

SPP# 1996-008

Team members

T Friend (0.55), S Hill (1.0), T Button (0.9), V Hack (0.5), S Schreck (0.5).

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 collaborative arrangements with South Coast NRM, 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 (2010/2011) 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 19 in June/July 2010, 21 in November 2010 and 16 in March 2011.
- The translocated population on Bald Island has grown rapidly from the founder number of 10. Forty-nine independent potoroos, including eight of the 10 founders from 2005–2007, were captured in the most recent full census in June 2010, despite the removal of a total of 21 potoroos (seven in September 2008 and January 2009 and 14 in September 2010). A field trip in June 2011 captured 39 potoroos in half of the trapnights, indicating that numbers have grown even higher.
- In February and March 2010, nine Gilbert's potoroos (including seven from Bald Island) were released into a 380ha fox- and cat-free enclosure in Waychinicup National Park. This release was followed by a transfer of eight potoroos from Bald Island in September 2010. As well as aiming to establish a new population, this project is structured as an experiment to compare the potoroos' use

of the different vegetation types within the enclosure. Some animals were released into an area of about 50ha of *Melaleuca striata* heathland identical to potoroo habitat at Two Peoples Bay, and others into different habitat. On release the potoroos were radio-tracked on several days each week for two months, by which time tail-mounted transmitters had fallen off. This methodology has shown that the potoroos can survive in habitat different from that preferred at Two Peoples Bay.

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.

Future directions (next 12–18 months).

- Continue to monitor the Mount Gardner population and the Bald Island translocation.
- Support cat trapping efforts at Two Peoples Bay, and initiate a 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 dynamics of the Two Peoples Bay population of Gilbert's potoroos will be submitted for publication.

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

SPP# 1993-163

Team member

T Friend (0.05).

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 (2010/2011) and main findings

A collaborative paper on the 'wart-like syndrome' has been published and the results incorporated into the Shark Bay Islands marsupial recovery plan.

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 12–18 months)

- The results of the cross-breeding experiment conducted at Kanyana Wildlife Rehabilitation Centre will be written up.
- A paper on home range activity and nest use by western barred bandicoots on Dorre Island is near completion and will be submitted for publication.

Probait trials: phase 2

SPP# 2000-014

Team member

N Marlow (0.05), P de Tores (0.01), R Hill (0.01).

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.

Aim

Ensure that Probaits contain a lethal dose of 1080 for fox control between baiting sessions.

Summary of progress (2010/2011) 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 effective.

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 12–18 months).

- Develop the protocols necessary to be able to accurately determine the concentration of 1080 in meat baits
- Test the amount of 1080 in baits during the manufacturing/ salami process and in baits exposed to field conditions.
- Undertake effective feral cat control in conjunction with fox control

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

SPP# 2006-007

Team members

N Marlow (0.85), A Williams (0.9), N Thomas (0.9), B Macmahon (1.0), J Lawson (0.1).

Context

The trap success for woylies (Bettongia penicillata) in Dryandra Woodland and Tutanning Nature Reserve increased dramatically following the introduction of fox baiting by Science Division staff 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 to be investigated. 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 had 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 (2010/2011) and main findings

- Monitoring of woylie populations in Dryandra Woodland and Tutanning Nature Reserve was undertaken and are currently being analysed.
- Analysis of the DNA obtained from feral cats indicated that most (8 of 9) feral cats involved in woylie predation were male and that some cats had been resident in Dryandra Woodland for more than two and a half years.
- Some fox predation of woylies continues to occur due to a very high uptake of baits by non-target species (birds and brush tailed possums) and thus baits not being available for fox control
- 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 which enter these areas as evidenced by the serendipitous collection of numerous fox carcasses.

Management implications

- The Western Shield monitoring of Tutanning Nature Reserve needs to be undertaken annually so that any changes in the trap success of woylies can be addressed as soon as possible.
- The development of an operational cat bait which is effective in killing cats throughout the year and in sites where non-target species are present is of paramount importance for predator control to allow recovery of woylie populations.

Future directions (next 12–18 months)

- Complete data analysis from monitoring in Dryandra Woodland.
- Facilitate the annual monitoring of woylies at Tutanning Nature Reserve.
- Incorporate the latest Western Shield monitoring data into the analyses resulting from the mesopredator project, complete a report all relevant manuscripts.

Return to Dryandra

SPP# 2003-002

Team members

N Thomas (0.1), N Marlow (0.05).

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 mammalian species within

large enclosures (two x 10 ha) 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 (2010/2011) and main findings

- Eight marl have been caught in the Return to Dryandra facility, indicating that they are persisting and that numbers are slowly increasing.
- A release of 25 bilbies to Perup was undertaken in October 2010; around 15 bilbies remain in the facility.
- In late 2010 the majority of remaining boodies (a total of 89 animals) were translocated to Lorna Glen leaving approximately three individuals within the facility.
- Mala numbers within the Return to Dryandra facility have been static at approximately 20 individuals.
- Bilbies are still persisting within Dryandra woodland but at extremely low numbers.

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 12–18 months)

- Undertake a proposed translocation of all mala to Lorna Glen in spring 2011 and discontinue breeding at Dryandra.
- Translocate remaining boodies to Lorna Glen in spring 2011 and discontinue breeding at Dryandra.
- When a suitable site has been found for marl, translocate all the marl and discontinue breeding at Dryandra.
- Dryandra to continue breeding bilbies for at least the next three years for future planned translocations.

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

SPP# 1993-053

Team members

K Morris (0.2), B Johnson (0.4).

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*. 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, Population 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 IUCN criteria for Vulnerable, and should be downlisted. However, a more detailed analysis of the distribution, abundance and population trend is required before this assessment is made.

Aims

- Ensure that chuditch persist within its present range at existing or increased population densities.
- Increase population numbers through the establishment of at least one population outside the present distribution.
- Review the conservation status of the chuditch using IUCN criteria, and revise the recovery plan if necessary.

Summary of progress (2010/2011) and main findings

- Ongoing monitoring at key recovery/translocation sites of Lake Magenta, Julimar and Kalbarri.
- Revised chuditch recovery plan submitted to DSEWPaC.
- Trial translocation from Julimar Conservation Park to François Péron National Park.
- Advice provided to the South Australian Department of Environment and Natural Resources on potential to reintroduce chuditch to Flinders Ranges.

Management implications

Review of conservation status against IUCN criteria recommended that the chuditch remain listed as Vulnerable, and the recovery plan was revised accordingly. A key area highlighted in the revised recovery plan was the need for further investigation into the impact of feral cats and feral cat baiting programs on chuditch abundance.

Future directions (next 12–18 months)

- Continue monitoring at key sites—Kalbarri, Julimar, Lake Magenta, Peron and jarrah forest sites.
- Obtain state and federal approvals for recovery plan.

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

SPP# 2006-009

Team Members

K Morris (0.1).

Context

This project is a component of the investigation into introduced predator control and sustained fauna recovery in Western Australia. It comprises part of DEC's contribution to the Invasive Animals CRC mesopredator release study and commenced in January 2006.

The 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 threat to 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 (2010/2011) and main findings

- No further field work.
- Completed IA CRC reports and continued with data analysis.

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

- Publish results and prepare final report for the Director General, DEC.
- Facilitate the annual monitoring of Lake Magenta by the District.
- Undertake simultaneous ground and aerial fox baiting at Lake Magenta.

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

SPP# to be allocated

Team members

K Morris (0.35), J Dunlop (1.0), E Miller (1.0), A Smith (0.3). Kalgoorlie Regional staff.

Context

Operation Rangelands Restoration commenced in 2000 with the acquisition of Lorna Glen and Earaheedy pastoral leases by the Western Australian government. This 600 000ha area lying across the Gascoyne and Murchison IBRA regions is now the site for an ecologically integrated project to restore rangeland natural ecosystem function and biodiversity. An important component of this is the reintroduction of 11 arid zone mammal species following the successful control of feral cats and foxes.

The area now comprising Lorna Glen once supported a diverse mammal fauna that was representative of the rangelands and deserts to the north and east. These areas have suffered the greatest in terms of mammal declines in Western Australia. The original vision for the Western Shield fauna recovery program was to expand introduced predator control and translocations beyond the south-west once an operational feral cat control program had been developed, and this was also recommended by the independent review of Western Shield in 2003.

Potentially Lorna Glen could support one of the most diverse mammal assemblages in arid Australia, and contribute significantly to the long-term conservation of several threatened species. Mammal reconstruction in this area will also contribute significantly to the restoration of rangeland ecosystems through activities such as digging the soil and grazing/browsing vegetation, and assist in the return of fire regimes that are more beneficial to the maintenance of biodiversity in the arid zone.

The first of the mammal reintroductions commenced in August 2007 with the release of bilby (*Macrotis lagotis*) and wayurta (*Trichosurus vulpecula*). Another nine species of mammal are proposed for reintroduction over the next 10 years.

Aims

- Reintroduce 11 native mammal species to Lorna Glen over the next 11 years.
- Re-establish ecosystem processes and improve the condition of a rangeland conservation reserve.
- Improve the conservation status of some threatened species.
- Develop and refine protocols for fauna translocation and monitoring.

Summary of progress (2010/2011) and main findings

- Mala and Shark Bay mice translocated into the enclosure.
- Ongoing monitoring of boodies and bandicoots inside the enclosure undertaken every 6–8 weeks.
- A further 89 boodies were translocated to the enclosure. Twenty-five of these were released into old boodie warrens on the outside of the enclosure and their survivorship monitored via radiotelemetry. Twelve of the 15 radio collared boodies were killed by wild dogs/dingos within three months of release. Subsequently a dog control program, in addition to a cat control program has been commenced at Lorna Glen.

Management implications

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

Future directions (next 12–18 months)

- Ongoing monitoring of bilbies and possums outside the enclosure, and of bandicoots, boodies, mala and Shark Bay mice inside the enclosure.
- Additional mala from Peron and Dryandra to be released into the pen.
- Continued monitoring inside and outside the enclosure for breaches/presence of feral cats, foxes and dogs.
- Develop a strategy for releases of boodies and bandicoots outside the enclosure, using the progeny of the founders.

Barrow Island fauna translocations

SPP# to be allocated

Team members

K Morris (0.35), B Johnson (0.2), B Muir (0.2), K Rusten (1.0), E Miller (0.7), A Smith (0.7), N Thomas (0.1), N Hamilton (0.1), A Burbidge (0.1), W Caton (0.1). Exmouth, Karratha and Kalgoorlie DEC staff.

Context

Following the state government approval of the Gorgon gas plant to be developed on Barrow Island in 2003, a series of Ministerial environmental conditions were imposed on the operator Chevron to ensure the unique conservation values of Barrow Island were maintained. These conditions included a 'threatened and priority species translocation and reintroduction program' which was aimed at establishing populations of selected Barrow Island fauna on other island and mainland sites, to improve the security of these species.

Aims

- Successfully translocate selected mammal and bird species from Barrow Island to other island and mainland sites.
- Contribute to improving the conservation status of some of these species.
- Ensure ongoing appropriate management at the translocation sites.
- Develop and refine protocols for fauna translocation and monitoring.

Summary of progress (2010/2011) and main findings

- The second year of the mammal and bird trapping program on Barrow Island was undertaken.
- The following translocations were undertaken: 40 boodies to Alpha Island (Montebellos), 92 golden bandicoots to Doole Island (Exmouth Gulf), 34 mala from Trimouille Island to Lorna Glen, 36 Shark

Bay mice from North West Island to Lorna Glen, and 22 spinifex birds and fairy wrens from Barrow Island to Hermite Island.

- Monitoring at the translocation sites has shown that bandicoots, hare-wallabies and birds have established well on Hermite Island and expanded their areas of occupancy. Bandicoots and boodies have established inside the fenced enclosure at Lorna Glen and populations have doubled in number. Only a few possums remain at Cape Range National Park where fox predation has been an ongoing issue despite an intensive fox control baiting program.
- A small number of mortalities of both mammals and birds has been recorded since these fauna were translocated from Barrow Island. The vast majority of these occurred very soon after translocation.
- Monitoring of translocated mammal populations indicates that all recaptured animals are in good to excellent physical condition, many females are pregnant and animals are actively exploring and moving away from the translocation sites.
- Regular updates on progress have been provided to the Minister via contentious issues briefing notes.

Management implications

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

Future directions (next 12–18 months)

- Research into effectiveness of fox baiting at Cape Range to be undertaken in August/September 2011.
- Ongoing monitoring of the translocated mammals and birds at all the release sites.
- Planning workshop for 2012 translocations to be held in November 2011.
- Annual report to be prepared as part of agreed governance arrangements.

Ecology and conservation of threatened pythons in Western Australia

SPP# 1993-159

Team member

D Pearson (0.1).

Context

With four of Western Australia's 11 taxa of pythons listed as threatened or in need of special protection, this long term project has collated distributional information to assess their conservation status more accurately, as well as conducting ecological studies of three species (south-west carpet python, Pilbara olive python and woma python). This has provided the first detailed studies of the habitat requirements, diet, and reproductive ecology of these taxa. Fieldwork components are largely complete with just an ongoing long-term mark-recapture study of carpet pythons continuing on Garden Island.

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.
- Collect material for future genetic work to aid wildlife forensics.

Summary of progress (2010/2011) and main findings

- Curation of collected specimens (road-kills) undertaken. Some specimens lodged at the Western Australian Museum.

- The 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 48 new and 16 marked individuals were processed during the year including the recapture of one male originally marked in 1998.

Management implications

- Data on the basic biology and conservation status has been obtained for three threatened species. Resource developments in the Pilbara will impact on the Pilbara olive python so data collected will be valuable for further surveys and formulating protocols to mitigate impacts.
- Data on home range and activity patterns will be valuable to assist in locating 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 12–18 months)

- Publication of telemetry studies on woma and Pilbara olive pythons.
- Necropsies of collected pythons for dietary and reproductive data and publication of life history information.
- Continuation of the long-term mark recapture study on Garden Island with a publication examining the long-term demographics of the population and size-related shifts in prey selection.

Implementation of the Lancelin Island skink recovery plan

SPP# 1999-011

Team member

D Pearson (0.1).

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 of a translocated population on Favorite Island.
- Revise 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 (2010/2011) and main findings

No fieldwork during this period. Advice provided to DEC's Midwest Region concerning a proposed coastal development in Lancelin.

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 12–18 months)

- Production of a paper on the successful translocation to Favorite Island.

- Assist regional staff as required to conduct periodic monitoring of the Lancelin and Favorite Island populations.

Improving rock-wallaby conservation and management

SPP# 2006-003

Team member

D Pearson (0.1).

Context

Five species of rock-wallabies occur in Western Australia. There are also a number of distinct subspecies and chromosomal races. Many taxa are threatened, primarily by feral animal predation, but inappropriate fire and introduced grazers also impact upon populations. This project seeks to improve management and monitoring of rock-wallaby populations.

Aims

- Prepare a recovery plan for the five species of rock-wallabies that occur in Western Australia.
- Survey and monitor black-footed rock-wallaby populations.

Summary of progress (2010/2011) and main findings

- A draft recovery plan has been prepared and was widely circulated for comment both within DEC and beyond. The plan was revised and a final draft is currently being prepared.
- A draft paper on the conservation status of the Nabarlek rock-wallaby has been prepared for submission to *Australian Mammalogy*.

Management implications

A recovery plan should aid in the prioritisation of actions to improve the conservation status of rock-wallabies in Western Australia and adjoining regions.

Future directions (next 12–18 months)

- Complete recovery plan and submit to Nature Conservation Branch for final consideration.
- Publication of papers on the distribution and conservation status of Nabarleks and the west Kimberley race of *Petrogale lateralis.*

Impact of cane toads on biodiversity in the Kimberley

SPP# 2006-004

Team members

D Pearson (0.5), B Stewart (0.2).

Context

Cane toads are perceived to constitute a serious threat to the biodiversity of the Kimberley and yet few 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 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 (2010/2011) and main findings

- Frog call data was 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) detected the death of just one king brown apparently due to its attempt to consume a cane toad.
- Submission of a paper to *Wildlife Research* on the ability of dunnarts to learn and avoid potentially deadly interactions with cane toad metamorphs.

Management implications

The project has followed the fate of several species believed to be at significant risk from cane toads during their invasion. It has collected information on the ecology of these species which will be valuable for other management. For instance, information on the foraging behaviour of the local olive python can be used to educate local land-holders and reduce unlawful killing. Telemetry on king brown snakes is an Australian-first for this large widespread elapid and will enable more effective monitoring of populations.

Field trials of CTA are ongoing and potentially provide a technique to retain populations of susceptible predators (goannas, large snakes and blue tongue lizards) in pockets across the Kimberley landscape.

Future directions (next 12–18 months)

- Testing of the CTA baits to teach naïve Kimberley predators to avoid toads and examination of any potential non-target effects.
- Resampling of frog survey sites during the 2011/2012 wet season to document the impact of toads now that breeding is occurring throughout the area and native species have to contend not just with adult toads, but also other growth phases.
- Publication of studies on the susceptibility of Kimberley snake and goanna species to poisoning from cane toads.

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

SPP# 2007-002

Team Members

A Wayne (0.5), C Ward (0.5), C Vellios (0.5), M Maxwell (0.5).

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 (*Wildlife Conservation Act 1950* and *Environment Protection and Biodiversity Conservation Act 1999* respectively). The cause(s) for these declines remains unknown.

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 (2010/2011) and main findings

- Ongoing monitoring indicates the overall median population decline has been 95% to 2010, from the 1999 peak of approximately 226 000 woylies. Keninup and Warrup were the largest remaining wild woylie populations in Western Australia and have been foci for research. The rate of declines in Keninup have continued but slowed in the last 12 months (~85% decline from March 2007 to April

2011). Warrup is the only Western Australian site known to have made a substantial post-decline recovery (2005–2008) but has subsequently declined again (90% since March 2009).

- Sand pad monitoring indicates that predator activity remains variable (spatially and temporally). Overall, fox activity continues to increase and cat activity is relatively stable.
- 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.
- Collaborative disease investigations continue particularly into the key associations with the declines.
- The establishment of the 423ha Perup Sanctuary was completed, including fauna surveys, herding out of large macropods and emus, and verification that it is free of mammalian predators. Extensive trapping throughout the Upper Warren sourced 41 woylies for Perup Sanctuary, eight for a native animal rescue facility and five for the Perth Zoo insurance population. Subsequent monitoring indicates good survival and successful recruitment by reproduction.

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 (e.g. ngwayir, wambenger, quokka, numbat, etc).

Future directions

- 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.

Conservation of Western Australian butterflies

SPP# 1993-022

Team members

M Williams (0.05), A Williams (0.05), T Gamblin (0.25).

Context

Invertebrates constitute a major part of the state's biodiversity. 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 is uncertain, using genetic methods to better delimit those taxa.

Summary of progress (2010/2011) and main findings

- Scientific paper published in the *Journal of Insect Conservation*.
- Bush Book completed—Rare and Endangered Butterflies of the South-West.

- Further surveys of the Critically Endangered arid bronze azure butterfly completed.
- Article on the ecology and conservation of the arid bronze azure published in *LANDSCOPE*.

Management implications

- Knowledge of butterfly populations is required for the assessment of impacts of proposed developments on conservation values of listed endangered invertebrates in the Wheatbelt and Swan Regions.
- More than 10 butterfly species are now locally extinct in the highly disturbed bushland remnants on the Swan Coastal Plain (SCP), and therefore some reserves are likely to be of critical importance in maintaining landscape biodiversity.
- It is becoming apparent that a translocation approach, currently used successfully for threatened vertebrates, will be necessary to maintain butterfly biodiversity of the SCP.

Future directions (next 12–18 months)

- Undertake ecological studies of arid bronze azure to provide basic information on its habitat requirements, distribution and conservation.
- Nominate the arid bronze azure for listing as a threatened species under the federal *Environment Protection and Biodiversity Conservation Act 1999.*
- Undertake further searches in the northern wheatbelt for extant arid bronze azure populations using community groups and local media outlets.

Conservation of the graceful sun-moth

SPP# 2010-006

Team members

C Bishop (0.8), A Williams (0.15), T Gamblin (1.0), J Fissioli (0.05), M Williams (0.15).

Context

This project focuses on a high-profile threatened invertebrate that is listed as an endangered species under the federal *Environment Protection and Biodiversity Conservation Act 1999*, and the *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 (2010/2011) and main findings

- A total of almost 140 sites have been surveyed over the past two years, with about half (63) having *S. gratiosa* present. Almost 1 000 person-hours of survey effort has provided detailed information on local population density, which shows enormous variation—from as low as one moth seen / 10 hrs of survey, to >10 moths/hr.

- The results have enabled a detailed map of the distribution to be produced, which extends from Binningup to Kalbarri. The species is confined primarily to habitat patches in a narrow strip of near-coastal dunes, with only a few small populations in Banksia woodlands.
- Genetic studies have found significant spatial structure, with the distribution divided into three main regions—Binningup to the Swan River, north of the Swan River to Cervantes, and a distinct, isolated northern population between Leeman and Kalbarri.
- A population in Wandoo National Park near York, was found to be the result of hybridization between *S. gratiosa* and the closely-related wheatbelt species *S. jcaria*.
- The early stages (larvae and pupae) have been located, confirming that the life cycle takes two or more years to complete. This potentially explains why the species seems to be absent from some sites in some years—cohorts 'leapfrog' each other, and one cohort may become locally or temporarily extinct.
- Information on distribution and population density will be used to re-assess the conservation status of the species, in light of its representation in conservation reserves and the impact of proposed developments on subpopulations.
- Ongoing advice has been provided to managers and regional staff, DEC's Species and Communities Branch, and DEC's Environmental Management Branch on the impacts of proposed developments and suitable mitigation actions.

Management implications

Information on the distribution, abundance and habitat requirements of the graceful sun-moth will enable assessment of conservation status and development of management strategies.

Future directions (next 12–18 months)

- Submit a review of the conservation status of the graceful sun-moth to the DEC Threatened Species Scientific Committee.
- Prepare a report on the findings for distribution to stakeholders, including the hundreds of volunteers, DEC staff, environmental consultants and developers who have contributed data to the project.

FLORA CONSERVATION AND HERBARIUM

PROGRAM LEADER: DR 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 which 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.

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

SPP# 1998-003

Team members

M Byrne (0.3), D Coates (0.15), N Gibson (0.05), B Macdonald (0.5), M Hankinson (0.1), S McArthur (0.1), K Shepherd (0.1), R Butcher (0.1), J Wege (0.1), K Thiele (0.1).

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.

Summary of progress (2010/2011) and main findings

- Taxonomic relationships have been investigated among putative entities of *Platytheca* sp. Sabina, *Hakea* aff. *prostrata*, *Pityrodia* sp. *Yilgarn*, and *Hydrocotyle scutellifera* and associated taxa.
- A paper detailing the most variable gene regions for phylogeographic analysis has been written.
- Analysis of phylogeographic structure in *Calothamnus quadrifidus* has been completed showing a diverse southern lineage with some more widespread areas of expansion and a more restricted but diverse northern lineage.
- Genotyping of populations of *Calothamnus quadrifidus* using amplified fragment length polymorphism (AFLP) markers has been undertaken to determine genetic structure in the complex.

Management implications

- Assessment of the genetic structure within collections of *Synaphea* from the Pinjarra Plains will inform taxonomic revision and determine identity of questionable populations of DRF taxa.
- Assessment of genetic differentiation in *Eremophila microtheca* and *E. rostrata* will assist in determination of sub-specific taxa, and clarification of DRF status.
- Assessment of genetic differentiation in *Calothamnus quadrifidus* will enable taxonomic revision of the group and identification of rare taxa.
- Possible taxonomic revision is required for *Pultenaea pauciflora* and revised assessment of conservation status.
- 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.
- 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.

Future directions (next 12–18 months)

- Analysis of *Eremophila microtheca* and *E. rostrata* will be completed to determine possible subspecies status within each species.
- Analysis of genetic structure within *Calothamnus quadrifidus* and allied taxa will be undertaken to inform taxonomic revision of the group. Phylogeographic structure in the complex will be published.
- Taxonomic revisions of *Platytheca* sp. Sabina, *Hakea* aff. *prostrata*, *Pityrodia* sp. Yilgarn, *Hydrocotyle scutellifera* and associated taxa will be completed.

Genetic and ecological viability of plant populations in remnant vegetation

SPP# 2002-001

Team members

D Coates (0.2), M Byrne (0.1), C Yates (0.1), T Llorens (0.6), S McArthur (0.3), N Gibson (0.05).

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.
- Compare results among three target taxa, *Calothamnus quadrifidus*, *Eremaea pauciflora* and *Eucalyptus wandoo*, in the Dongolocking area of the wheatbelt, with varied ecologies to assess how life history affects the impact of remnant characteristics on population viability.
- Directly quantify patterns of pollen movement and seed dispersal for *Banksia sphaerocarpa* in a highly fragmented 10 x 20km area south of Harrismith in the south western wheatbelt.
- Assess the importance of gene flow to the reproductive output and population dynamics of patch populations of *Banksia sphaerocarpa* by quantifying the relative frequency of local versus immigrant mating events, and then comparing the fitness of resulting seedlings in growth trials as well as contrasting the overall demographic performance of high and low gene flow sites.
- 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 (2010/2011) and main findings

- A manuscript assessing the influence of different aspects of habitat fragmentation on mating patterns and pollen dispersal in *Banksia sphaerocarpa* has been written and submitted to the journal *Molecular Ecology*. A draft journal paper detailing the genetic structure in the *B. sphaerocarpa* study area has been written.
- In *Banksia sphaerocarpa*, most mating system and pollen dispersal measures showed 'healthier' levels in the large study population compared with eight small highly fragmented study populations. Population size, isolation, shape (a measure of population linearity) and density showed significant linear relationships with certain mating system and pollen dispersal parameters, providing a rare insight into how different physical aspects of fragmentation may operate to affect the mating system. These results suggest that the effect of linear population shape on mating system and pollen dispersal is often underestimated.
- Analyses of the influence of habitat fragmentation and mating system variables on reproduction and progeny fitness in *Banksia sphaerocarpa* have been completed. Changes in the mating system caused by population fragmentation including reduced outcrossing, number of fathers per seed crop and neighbourhood size 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.
- Draft papers on pollen dispersal and reproductive biology have been written for *Banksia nivea* subsp. *uliginosa.*

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 (but at unknown cost in terms of one large site versus many small sites tradeoffs) 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. That is, it is very useful to know when thresholds for viability have been reached so that limited management and restoration efforts can be redeployed to other areas where gains can be maximised.

Future directions (next 12–18 months)

- Submit manuscript on the reproductive and fitness response of *Banksia sphaerocarpa* to habitat fragmentation for review and publication.
- Submit manuscript on the genetic structure of *Banksia sphaerocarpa* for review and publication.
- Write papers on mating system variation and reproductive output in *Eremaea pauciflora*, genetic diversity in *Eucalyptus wandoo* and genetic diversity in *Calothamnus quadrifidus*.
- Write papers on genetic diversity, pollen dispersal and mating systems in *Calothamnus* sp. *Whicher*, *Hakea oldfieldii* and *Banksia nivea* subsp. *uliginosa.*
- Write papers on reproductive biology and demography in *Calothamnus* sp. *Whicher*, *Hakea oldfieldii* and *Banksia nivea* subsp. *uliginosa.*

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 (0.2), M Byrne (0.1), S McArthur (0.1), M Millar (0.1).

Context

Understanding the interactions 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 (2010/2011) and main findings

- Data analysis of microsatellite genotypes completed for 13 extant and five extinct populations of *Banksia brownii*. Paper in preparation.
- Paper on the disparate levels of clonality, genetic diversity and genetic differentiation in subspecies of *Banksia ionthocarpa* published in *Molecular Ecology*.
- Paper on temporal and spatial patterns of mating system variation in *Banksia cuneata* and *Lambertia orbifolia* submitted to *Annals of Botany*. Further data analysis and redrafting for resubmission 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* and *Lambertia orbifolia* 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 12–18 months)

- Finalise paper on 'Population genetic structure and mating system variation in *Verticordia fimbrilepis* subsp. *fimbrilepis*'.
- Resubmit paper on temporal and spatial patterns of mating system variation in *Banksia cuneata* and *Lambertia orbifolia* to *Annals of Botany*.
- Submit for publication paper on genetic structure and the impact of localised extinction on genetic diversity levels in *Banksia brownii.*
- Complete genotyping and analysis of the mating system in two sister species, *Stylidium affine* and *Stylidium maritimum*, with contrasting breeding systems.

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 (0.1), M Millar (0.9).

Context

Acacia woodmaniorum is a recently described species endemic to the Blue Hills banded ironstone ranges of the Midwest region. Known from ~ 29 000 plants and restricted to an area of about 40km^2, the species is gazetted as 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. This study investigates the detailed genetic structure within this species as a basis for estimating loss of genetic diversity due to potential impacts from mining. Phylogenetic and phylogeographic relationships between this rare species and its more common close relatives will also be investigated to better understand its origins, whether rarity is associated with habitat specialisation or historical circumstances and the origins of the unique banded iron formation flora.

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 (2010/2011) and main findings

- Direct paternity analysis confirms high levels of pollen mediated gene flow among populations.
- The mating system is predominantly outcrossed.
- Initial results indicate little variability in chloroplast regions for *Acacia woodmaniorum*.
- Twenty-four-month and 30-month reports have been provided to Karara Mining Ltd.

Management implications

- Populations likely to be impacted by mining activities may play an important role in maintaining species connectivity.
- Areas that may require specific rehabilitation have been identified.
- Identification of pollinators and seed dispersers may assist in the maintenance of outcrossing rates among populations.

Future directions (next 12–18 months)

- Identify DNA sequences of sufficient variation to provide phylogenetically informative data in *Acacia woodmaniorum, A. restiacea* and *A. cerastes*. Sequence populations of *A. woodmaniorum, A. restiacea* and *A. cerastes* and analyse data.
- Publish paper on genetic diversity.
- Publish paper on mating system and gene flow.
- Publish paper on phylogeographic patterns in *Acacia woodmaniorum* and its closest relatives.
- Provide final report to Karara Mining Ltd.

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

SPP# 1999-010

Team members

A Cochrane (0.4), A Crawford (0.9), A Monaghan (0.5), S Dudley (0.3), B Elkins (0.5), D Coates (0.05).

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 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 (2010/2011) and main findings

- Stocktake conducted of all collections held at the Threatened Flora Seed Centre in preparation for the move to the new Western Australian Conservation Science Centre.
- Three hundred and forty collections cleaned and stored (221 DRF, 64 Priority and 55 common collections).
- Material of 159 collections duplicated for safekeeping with the Millennium Seed Bank Project in the UK to complete agreed project targets.
- Germination tests conducted on 106 collections (47 DRF, 15 priority and 44 common collections).
- Provision of germinated seeds for translocation of critically endangered flora.
- Germination report provided to Millennium Seed Bank Project to cover seed duplicated in the UK since 2001.
- Seed collections from 89 rare, threatened and priority flora incorporated into seed bank under the South Coast NRM Stirling Range National Park Threatened Ecological Community project.
- Paper on *Banksia* seed longevity published in *Annals of Botany.*
- Paper on collecting and storing rare seeds presented at the International Plant Propagators Society Conference.

Management implications

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

Future directions (next 12–18 months)

- Ongoing research into seed biology and seed storage behaviour of threatened plant taxa.
- Germination testing, storage and monitoring of existing collections.
- Seek funding for seed collection activities through the Australian Seed Bank Partnership 1 000 Species Project.
- Complete Millennium Seed Bank Project Transition Phase final report in conjunction with Botanic Gardens and Parks Authority.
- Publication on seed germination thresholds in *Banksia*.

Translocation of critically endangered plants

SPP# 2001-004

Team members

L Monks (0.6), R. Dillon (1.0), D Coates (0.05).

Context

In order for translocations of threatened flora to contribute to the successful recovery of species it is important that best practice techniques are developed and there is clear understanding of how to assess and predict success.

Aims

- Develop appropriate translocation techniques for a range of critically endangered flora.
- Develop detailed protocols for assessing and predicting translocation success.
- Establish a translocation database for all threatened plant translocations in Western Australia.

Summary of progress (2010/2011) and main findings

- Infill planting was completed for translocations of eight critically endangered plant species.
- Monitoring was undertaken for 13 translocations planted in previous years.
- Ongoing development of flora translocation database continuing in collaboration with Species and Communities Branch.
- Completed book chapter on translocation success of long-lived plants to be published in “Plant Reintroduction in a changing climate: promises and perils”.
- Completed paper on mating system study of *Lambertia orbifolia* translocation, commenced writing paper on *Acacia* translocation success.

Management implications

- Translocations lead to improved conservation status for critically endangered plant taxa.
- Improved awareness of best practice translocation methodologies for DEC staff and community members undertaking such work will lead to greater translocation success.
- 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 12–18 months)

- Continue the planting of experimental translocations of critically endangered plant species where further plantings are deemed necessary.
- Continued monitoring of the 32 translocations and analyses of population biology data.
- Publish translocation methodology data, translocation summary data, *Lambertia orbifolia* population viability modelling data and *Acacia* translocation success study.

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

SPP# to be allocated

Team members

P Poot (0.4), M Moody (0.05), R Dillon (0.1), L Monks (0.05), D Coates (0.05).

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 setup 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'.
- Develop a more efficient rare flora translocation program firmly based on scientific findings.

Summary of progress (2010/2011) and main findings

- An experimental translocation has been published using 475 seedlings of the Critically Endangered *Dryandra ionthocarpa* subsp. *ionthocarpa* in Kamballup Nature Reserve. This experiment involved different pre-treatments (seedlings grown on washed river sand and on standard Kings Park potting mix), different microhabitats (open areas, removed low open heath and removed tall closed heath), different planting times (early May versus early July), and different watering regimes (monthly hand watering over summer and frequent automatic watering). So far (March 2011), survival has been 84% and some interesting differences amongst combinations of treatments have developed.
- An experimental translocation has been established using 863 seedlings of the Vulnerable *Acacia awestoniana* in the Stirling Range National Park. Because of a relatively recent fire this species currently has less than 10 reproducing adults remaining. This experimental translocation involved different pre-treatments (seedlings grown on washed river sand and on standard Kings Park potting mix), different microhabitats (open areas in between wandoo trees versus directly under wandoo trees), and different watering regimes (monthly hand watering over summer, frequent automatic watering and non-watered controls). So far (March 2011), survival has been 81% and despite the dry summer the non-watered plots have not suffered a higher mortality, although they did have reduced growth compared to watered plots

Management implications

- Increased understanding of the factors that are most relevant to translocation success will improve the conservation status of *Dryandra 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 for DEC staff, community groups and industry.

Future directions (next 12–18 months)

- Continue monitoring environmental conditions, health and physiological activity of the 1 300+ seedlings of the two species that have been transferred so far, to determine the effects of seedling pre-treatments, site microhabitats, watering treatments and planting times.

Ecophysiology of rare flora restricted to shallow-soil communities

SPP# to be allocated

Team member

P Poot (0.1).

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.

Aim

Enhance our knowledge of the key adaptations of species endemic to shallow-soil habitats, and how these adaptations may restrict them in their distribution.

Summary of progress (2010/2011) and main findings

- Continued data analysis.
- Preparation of a manuscript on root allocation and morphology of 'granite outcrop/non-granite outcrop' congeneric species pairs.

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 (i.e. they are bare for a reason—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 12–18 months)

- Write up and submit the ironstone species work on phenotypic plasticity, and the work on granite outcrop species.
- Present an overview of the shallow-soil work at the Ecological Society of America meeting in August 2011 in Texas and use this opportunity to instigate collaborations.
- Work on a modelling paper with Dr Michael Renton (UWA, Plant Biology) to better understand the dynamics of recruitment on shallow-soil communities and its relationship with species' dispersal abilities and root system morphologies.

The population ecology of critically endangered flora

SPP# 2000-015

Team Member

C Yates (0.1).

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 Declared Rare Flora (DRF) and threatened ecological communities.

Aim

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

Summary of progress (2010/2011) and main findings

- Continued monitoring the effect of fire interval on plant species richness and abundance in the Critically Endangered eastern Stirling Range Montane Heath and Thicket community.
- Continued monitoring the demography of DRF and other taxa of conservation significance in the Critically Endangered eastern Stirling Range Montane Heath and Thicket community.
- Continued monitoring the demography of the Critically Endangered *Verticordia staminosa* subsp. *staminosa* in relation to climate change.
- Published *Verticordia fimbrilepis* subsp. *fimbrilepis* population viability analysis exploring role of fire in managing the taxon in *Plant Ecology*.

Management implications

- The research in the eastern Stirling Range Montane heath and thicket community is yielding valuable information about the impact of fire interval on floristic diversity, fire response strategies and life histories of DRF and other vascular plant species. This will contribute to the development of ecologically appropriate fire regimes.
- Prescribed fire will be needed for *Verticordia fimbrilepis* subsp. *fimbrilepis* to persist in long unburnt wheatbelt fragments.

Future directions (next 12–18 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*.

Causes of rarity in four Tetratheca taxa in the Goldfields Ranges

SPP# 2000-015

Team members

C Yates (0.1), N Gibson (0.1).

Context

The eastern Goldfields ranges are local hotspots of plant diversity with many endemic taxa. This project centres on the Critically Endangered *Tetratheca paynterae* subsp. *paynterae* found at Cliffs Windarling mine, and three other threatened *Tetratheca* taxa on adjacent ironstone ranges with mining prospects, *T. paynterae* subsp. *cremnobata* found on the Diehardy Range; *T. harperi* found on the Mount Jackson ranges; and *T. aphylla* found at the Helena and Aurora ranges. The project is investigating the

environment, reproductive biology and demography of the ironstone *Tetratheca* taxa and patterns of plant diversity in associated shrubland communities.

Aims

- Describe and compare the physical environmental domains of the four banded iron formation (BIF) *Tetratheca* taxa and associated floristic assemblages to assist with identifying sites and techniques for translocation.
- Describe and compare the reproductive biology of the four BIF *Tetratheca* taxa.
- Describe and compare the population structures and demography of the four BIF *Tetratheca* taxa.
- Construct models of population dynamics for exploratory investigation of the potential impact on population viability of further reducing the number of plants in the *T. paynterae* subsp. *paynterae* population and other disturbances.

Summary of progress (2010/2011) and main findings

- Published a manuscript on the floristic assemblages of the BIF ranges where the four *Tetratheca* species occur in *Biodiversity and Conservation*.
- Submitted a manuscript describing the habitats, population dynamics and feasibility of translocation as a conservation action for the four *Tetratheca* species.

Management implications

- These xeric shrublands on the four BIF ranges are structurally and compositionally different from the surrounding matrix and exhibit high levels of endemism and species turnover that cannot be ascribed to geology or current climatic gradients. The pattern of the vegetation and flora on these ranges appears to be related to local topographical factors and the long period of time these landscapes have remained unglaciated and above sea level. The high correlation between local endemism and restricted plant communities and high grade mineral deposits presents difficult challenges for achieving a comprehensive, adequate and representative reserve system in Western Australia.
- The geographic restriction of the BIF *Tetratheca* to single BIF ranges and their highly specific habitats, restricts options for translocating the taxa if habitat is destroyed by mining. The restriction of three of the taxa to narrow fissures excludes the option of using seedlings in reintroductions. Using seeds, while possible, will be both an inefficient and a high risk strategy for at least three of the four taxa studied. This is because of the low frequency of winter rainfall sufficient to stimulate high rates of seed germination, coupled with the consistently high rates of seedling mortality in most years, and no easy method for determining which rock fissures will be suitable for plant establishment. The fourth more widespread taxon showed similar reproductive and demographic characteristics to the taxa restricted to the narrow fissures indicating that translocation will also be risky for this species.

Future directions (next 12–18 months)

No further work planned.

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 member

C Dunne (0.45).

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 (2010/2011) and main findings

- Completed the monitoring of the efficacy of the high intensity phosphite application at three locations in the South Coast Region. Results to date have shown that high intensity phosphite treatment can retard front movement, reduce soil *Phytophthora* inoculum, and decrease mortality rates in target susceptible species. The treatment works best in Proteaceaous healthland on deep sands.
- Monitored the efficacy of high intensity phosphite using Digital Multispectral Imagery to prevent disease centre extension and minimise the impact of *P. cinnamomi* at the Bell Track infestation within the Fitzgerald River National Park.
- Developed a range of new novel techniques for the eradication of spot infestations of *P. cinnamomi* on the south coast of Western Australia.
- Submitted a technical paper on the 'Last Stand at Bell Track' project to the *New Zealand Journal of Forest Science*.
- Drafted a paper on the 'Seasonality of *P. cinnamomi* from the National Parks on the south coast of Western Australia'.

Management implications

- Improved efficacy of phosphite treatment to control *P. cinnamomi* means this technique is now being used at the Bell Track infestation in the Fitzgerald River National Park to contain the pathogen to its current micro-catchment.
- Increased understanding of disease epidemiology will allow for more accurate modelling of disease centre extension.
- Improved management of *P. cinnamomi* through the use of appropriate hygiene practices will prevent further spread of infections.
- Improved field diagnostics for determining the presence and absence of the pathogen in soil and plant tissue samples will enable greater accuracy in identification of infections.
- Development of eradication and containment techniques for quick response to new *Phytophthora* dieback infestations within priority protection areas across the south-west of Western Australia.

Future directions (next 12–18 months)

- Undertake monitoring of the eradication and containment sites within Cape Arid and Fitzgerald River national parks.
- Undertake soil and plant tissue analysis of phosphorous and phosphite levels within natural ecosystems with a history of phosphite treatment.
- Publish the research findings on the high intensity phosphite research field trials.

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

SPP# 1993-068

Team members

B Shearer (0.5), C Crane (0.1).

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, established in 1979, was designed as a series of long-term experiments.

Aim

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

Summary of progress (2010/2011) and main findings

- Published four papers.
- Submitted paper on variation in phosphite efficacy between *Lambertia* taxa.
- Prepared results of injection and spray trials for publication.

Management implications

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

Future directions (next 12–18 months)

- Submit injection and spray trials for publication.
- Prepare and submit paper on variation in phosphite efficacy between taxa.

Susceptibility of rare and endangered flora to *Phytophthora*

SPP# 1999-019

Team members

B Shearer (0.5), C Crane (0.1).

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, established in 1996, 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 (2010/2011) and main findings

- Published a paper on variation in susceptibility to *P. cinnamomi* within the genus *Lambertia.*
- Analysed susceptibility of *Banksia* (including *Dryandra*) to *P. cinnamomi*
- Presented a poster at the 8th National Conference of the Australian Network for Plant Conservation.
- 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 12–18 months)

- Update database and analyse trends within database.
- Prepare for publication a paper on variation in susceptibility to *P. cinnamomi* within *Banksia*.
- Analyse susceptibility of threatened flora to *P. cinnamomi*.

- Determine variation in susceptibility (with A. Cochrane) of four *Banksia* species across a climate gradient on the south coast.

Mundulla Yellows disease in Western Australia

SPP# to be allocated

Team member

M Stukely (0.15).

Context

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 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. 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.

Aims

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

Summary of progress (2010/2011) and main findings

- Monitoring of MY in Western Australia by DEC has continued. Newly observed MY-affected sites have been checked and sampled. 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.
- Seedlings are being grown on in the glasshouse for testing in transmission trials.

Management implications

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.

Future directions (next 12–18 months)

- Continue monitoring of existing and new occurrences of MY in Western Australia.
- SPP to be prepared.
- Prepare for publication a scientific paper on soil and foliar nutrient data from Western Australian sites.
- Harvest foliar material from seedling transmission trials in the glasshouse for testing for molecular markers.

Vegetation Health Service

Core Function

Team members

M Stukely (0.25), J Webster (0.6), J Ciampini (0.4).

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 the state'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.

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 which is available to external customers on a fee for service basis.
- Provide advice to assist departmental personnel 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. Provide input for the preparation of departmental management plans. Liaise with external biosecurity authorities (state and national) and Department of Agriculture and Food of Western Australia (DAFWA), as required.
- Maintain the VHS's live *Phytophthora* Culture Collection and the Western Australian *Phytophthora* database, and continue to make these resources available to researchers and land managers.
- Facilitate and collaborate in research on *Phytophthora*, both within DEC and externally.

Summary of progress (2010/2011) and main findings

- A total of 1 755 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.
- The live *Phytophthora* Culture Collection and Western Australian *Phytophthora* database have been maintained, expanded and updated, and are available to researchers and land managers.
- A paper on the occurrence in Western Australia of unique *Phytophthora* hybrids was presented at the 18th Biennial Conference of the Australasian Plant Pathology Society, Darwin, NT, 26-29 April 2011.
- The formal descriptions of the following new Western Australian species were published (with CPSM): *Phytophthora elongata* (*P*.sp. 2); *P. gregata, P. gibbosa, P. litoralis* and *P. thermophila* (*P*.sp. 7-i, *P*.sp. 7-ii, *P*.sp. 11 and *P*.sp. 3, respectively); and *P. arenaria* and *P. constricta* (*P*.sp. 1 and *P*.sp. 9, respectively). *Phytophthora* taxon paludosa (from Victoria) was also described.
- The formal description of *Phytophthora fluvialis* (*P*.sp. 8) was submitted for publication (with CPSM).
- The formal descriptions of more new *Phytophthora* species are in preparation for publication.
- Advice to assist departmental personnel and the public has been provided, and input to departmental management plans was supplied.

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 quite distinct taxa that had previously been grouped and treated as single morpho-species. Knowledge of the pathogenicity, distribution and environmental requirements of these new and different phytophthoras is essential to enable estimates to be made of the level of threat they pose to biodiversity, and to develop appropriate strategies for their monitoring, management and control. It may not be appropriate to treat all species in the same way as *P. cinnamomi.* Most of the undescribed *Phytophthora* taxa have been associated with dying native plants in Western Australia, which is a clear indication that they have pathogenic capability in natural ecosystems.
- The existence of putative *Phytophthora* hybrids associated with dying plants in Western Australian native ecosystems, in addition to the new taxa, indicates that *Phytophthora* species interactions may need to be considered as part of a broader approach to *Phytophthora* management.

Future directions (next 12–18 months)

- Continue to verify field dieback-interpretation by testing of soil and plant samples.
- Maintain and expand the live *Phytophthora* Culture Collection and Western Australian *Phytophthora* database.
- Continue the DNA sequencing of new *Phytophthora* isolates, as well as historical isolates from the VHS culture collection, through the CPSM.
- Continue collaborative research with CPSM on the *Phytophthora* spp. nov., including species descriptions, and on the putative *Phytophthora* hybrids.
- Further develop draft recommendations for managing phytophthoras other than *P. cinnamomi*.
- Continue to provide advice to assist departmental personnel and the public in dealing with *Phytophthora* dieback and other plant disease problems; provide input for the preparation of departmental management plans; and liaise with external biosecurity authorities (state and federal) and DAFWA.

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

SPP# 2011-013

Team member

G Keighery (0.1).

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.

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 the following:
    - *Adenanthos pungens*; taxonomic status of two named subspecies;
    - *Calytrix breviseta*; status of hills population and taxonomic status of two named subspecies;
    - *Hypocalymma angustifolum;* taxonomic status of Yerina Springs;
    - *Adenathos eyeri / A. forrestii / A. ileticos* species complex; resolution of taxa;
    - taxonomy of *Cynoglossum* in Western Australia;
    - *Grevillea curviloba* and *Grevillea evanescens* taxonomy.

Summary of progress (2010/2011) and main findings

- Conservation status of the flora of Swan Coastal Plain, including ecotypes and morphological distinct variants completed for Ferns through Monocotyledons. Preliminary paper published in Australian Plant Conservation.
- Checklist of weeds of Nullarbor published.
- Checklist of naturalised *Prunus* species (Roasaceae) and *Psylliostachys* (Plumbaginaceae) published.
- Weeds of Pilbara published.

Management implications

- The conservation status of *Grevillea* sp. Gillingarra needs to be evaluated for protection of the species.
- *Salsola australis,* currently considered to be a widespread weed, has now been shown to be comprised of mainly native species, requiring reconsideration of management actions.

Future directions (next 12–18 months)

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

Wattles of the Pilbara

SPP# 2004-022

Team members

B Maslin (0.05), S van Leeuwen (0.1).

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.

Aim

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

Summary of progress (2010/2011)

The CD “Wattles of the Pilbara” was published and is now available for purchase through DEC. Gratis copies were distributed to the corporate sponsors and others who helped with the project.

Management implication

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

Future directions (next 12–18 months)

A reassessment of the taxonomic status of one Pilbara wattle, *Acacia catenulata* subsp. *occidentalis*, will be undertaken following examination of specimens of the typical subspecies at the Queensland Herbarium.

Conservation status and systematics of Western Australian *Acacia*

SPP# 2003-008

Team members

B Maslin (0.2), J Reid (0.1).

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.

Aim

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

Summary of progress (2010/2011) and main findings

- *Acacia saligna*: limited herbarium studies were undertaken to progress the taxonomic revision of this species.
- 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.

Management implications

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

Future directions (next 12–18 months)

- Complete taxonomic revision of *Acacia saligna.*
- Present paper on *A. saligna* at a workshop sponsored by World Vision on uses of *Acacia* as a human food.

Understanding mulga

SPP# to be allocated

Team members

B Maslin (0.1), J Reid (0.45), J Sampson (0.1). External Collaborators: J Miller, Australian National Herbarium, Canberra, R Rutishauser, Uni Zurich.

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.

Aim

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 (2010/2011) and main findings

- A taxonomic revision of Western Australian mulga species was completed and has been submitted to *Nuytsia* for publication.
- 12 mulga species (many new to science) have been recognised for Western Australia.

Management implications

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

Future directions (next 12–18 months)

- Progress the Western Australian mulga revision through publication.
- Undertake mulga identification workshops to facilitate identification of the species.

Australian wattle identification

SPP# to be allocated

Team members

B Maslin (0.6), J Reid (0.45), C Parker (0.1), K Thiele (0.1).

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.

Aim

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

Summary of progress (2010/2011) and main findings

- Visits to Australian herbaria (Canberra, Adelaide, Brisbane) undertaken to verify and update data for species.
- Interactions with Australian Biological Resources Study and custodians of the Australian Plant Name Index undertaken to progress delivery of descriptive and nomenclatural data. Tools to facilitate this delivery are under construction and staff training in their use has been completed.
- Work commenced on updating and verifying encoded data in WATTLE database commenced.
- Interactions with institutions and individuals undertaken to acquire photographs for delivery via WATTLE.

Management implications

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

Future directions (next 12–18 months)

- Provide an effective and accurate WATTLE identification key to all described Australian taxa of *Acacia* on the web.
- For each taxon provide current descriptive and associated information and (where available) photographs.

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

SCP# 2011-002 (SPP# to be allocated)

Team Member

R Butcher (0.5).

Context

Tephrosia is a large, pantropical legume genus comprising *c.* 400 species of herbs and shrubs. Sixty-one taxa are currently recognised in the Eremaean and Northern Botanical Provinces of Western Australia, including 18 phrase-named taxa and five manuscript-named taxa. Field surveys and study of specimens at the Western Australian Herbarium indicate that there are likely to be additional undescribed taxa in the Kimberley and Pilbara bioregions.

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; 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 conservation status.

Aims

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

Summary of progress (2011/2011) and main findings

- A total of 749 *Tephrosia* specimens had their identifications corrected. The WAHerb database was updated accordingly, leading to a revised understanding of the abundance and distribution of all Western Australian taxa.
- Two pre-existing species and one new published name were placed on the *Western Australian Plant Census* after they were determined to occur in Western Australia.
- Seven new informal phrase names were placed on the *Western Australian Plant Census* to encompass specimens that could not be identified under the existing taxonomy. Five of these were new taxa for Australia. The remaining two phrase names were already recognised in the Northern Territory, but were new records for Western Australia. Two of these newly-erected phrase names were recommended for listing on the *Declared Rare and Priority Flora List for Western Australia*.
- Six pre-existing phrase-named taxa from Western Australia were found to also occur in the NT, but under different phrase names. These disparate names are currently being harmonised as part of the *Australian Plant Census* project.
- Field work in the Eremaean Botanical Province resulted in the acquisition of 57 specimens of *Tephrosia*, including 19 new populations, eight of which were new records for phrase-named taxa. Photographs were also obtained for 14 *Tephrosia* taxa currently lacking images on FloraBase.

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 months)

- Conduct further field studies on poorly collected and taxonomically difficult species groups.
- Assess the taxonomy of new *Tephrosia* taxa in Western Australia and formally describe new species.
- Add and remove *Tephrosia* taxa from the *Western Australian Plant Census*, as required; and make recommendations regarding the appropriate conservation listing of taxa in Western Australia.
- Complete a *Tephrosia* DNA barcoding pilot study in conjunction with researchers at the University of Guelph, and commence a larger study if this is successful.
- Commence the construction of written and electronic identification tools.

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 (0.5).

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.
- Complete a *'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 (2010/2011) and main findings

- Draft flora treatments for members of the Myrtaceae tribe Chamelaucieae have been submitted to Australian Biological Resources Study (ABRS), and no further work is required until treatments by other authors have progressed to the point where publication becomes feasible.
- A paper introducing the interactive key to the Myrtaceae tribe Chamelaucieae is to be submitted soon and a poster on this topic will be presented at the XVIII International Botanical Congress (IBC) in July 2011.
- Five papers were published in 2010, one on *Isopogon* (Proteaceae), one on the Thymelaeaceae, one naming the new genus *Enekbatus* (Myrtaceae) and two other papers on the Myrtaceae (dealing with *Micromyrtu*s and *Hypocalymma,* respectively).
- A paper on *Petrophile* (Proteaceae) is scheduled for publication later this year, and an abstract for the IBC2011 poster has been submitted.

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 12–18 months)

- Official release of the interactive key through publication of an introductory paper in *Nuytsia* and a poster presentation.
- Continue updating and improvement of the interactive key and investigate the option of expanding the interactive key to include *Chamelaucium* and *Darwinia* by collaboration with additional authors.

- Submit papers on *Astartea* and *Cyathostemon* (Myrtaceae).
- Further work on two studies in the Proteaceae, one involving new species in *Isopogon* and the other using cladistics to investigate sectional boundaries in *Petrophile*.

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

SCP# 2009-006 (SPP# to be allocated)

Team Members

R Butcher (0.5), M Hislop (0.4), A Markey (0.05), K Shepherd (0.2), J Wege (0.1), C Wilkins (0.6).

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 1 600 putatively new and undescribed taxa in Western Australia, a significant proportion of which are poorly known, geographically restricted and/or under threat (i.e. declared rare or priority flora). The lack of detailed information on these taxa makes accurate identification problematic and inevitably delays DEC's ability to survey and accurately assess their conservation status.

Aim

Resolve the taxonomy, and expedite the description, of manuscript or phrase-named plant taxa, particularly declared rare and priority flora and those taxa vulnerable to future mining activities.

Summary of progress (2010/2011) and main findings

- Five taxonomic manuscripts were published in *Nuytsia* (*Acrotriche*, *Ptilotus*, *Stylidium*, *Tetratheca*) and two in *Telopea* (*Eragrostis*, *Tecticornia*). A further eight manuscripts were submitted for publication (*Androcalva*, *Commersonia*, *Dielsiodoxa*, *Leucopogon*, *Petrophile*, *Ptilotus*, *Sida*, *Stylidium*). Together these publications contain up to date descriptive information for 111 taxa, 35 of which are new to science, and 29 of which are listed as being of conservation concern.
- An improved taxonomic understanding of species complexes within Astroloma, Atriplex, Calytrix, Fimbristylis, Geleznowia, Lasiopetalum, Leucopogon, Pityrodia, Seringia, Stylidium, Styphelia, Synaphea, Thomasia, Tecticornia and Vigna was achieved. Twelve phrase-names have been added to *Western Australia's Plant Census* and draft descriptions generated for a range of taxa.
- *Stylidium* sp. Yalgoo (D Coultas et al. Opp 01) was gazetted as Declared Rare Flora and a further eight taxa were newly added to the *Declared Rare and Priority Flora List for Western Australia*.
- Field studies resulted in the acquisition of *c*. 125 herbarium specimens for the state collection, including several new populations of conservation-listed taxa.
- Team members collectively provided expert determinations for *c*. 350 specimens housed at the Western Australian Herbarium, and a further *c*. 200 collections by DEC staff or external consultants.

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 months)

- Assess and formalise the taxonomy of new Western Australian plant taxa, particularly those of conservation significance.
- Conduct field studies on poorly collected and taxonomically difficult species groups.

- Add and remove taxa from the *Western Australian Plant Census*, as required, and make recommendations regarding the appropriate conservation listing of Western Australian plants.

Taxonomy of selected families including legumes, grasses and lilies

SPP# 2011-001

Team members

T Macfarlane (0.7), R Cranfield (0.4).

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 un-named 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 current focus is on *Austrodanthonia*, *Wurmbea*, *Thysanotus* and *Lomandra*.

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.
- Provide botanical support for FORESTCHECK project.

Summary of progress (2010/2011) and main findings

- *Wurmbea* (Colchicaceae): a paper describing a new species was accepted by a journal (with A. Case); field work in the Midwest resulted in the discovery of new species and additional populations of poorly known species, and furnished additional specimens and photos. A talk was presented at a conference and a paper published in the conference proceedings.
- Hydatellaceae: published paper on pollination mode and life history aspects of *Trithuria submerse,* assisted with the preparation of an Interim recovery plan for the Critically Endangered *Trithuria occidentalis*.
- *Centrolepis* (Centrolepidaceae): paper published on a new interpretation of inflorescence structure (with Sokoloff, Remizowa, Linder and Rudall).
- A neglected wetland plant community in the Muir-Unicup Salinity Recovery Catchment was assessed for conservation value and the occurrence of new or range-restricted plants (*Trithuria, Riella*). A conference talk was presented and a paper published in the conference proceedings (with R.W. Hearn).
- *Austrodanthonia* (Poaceae): research and description preparation for an undescribed Wheatbelt species.
- Poaceae: paper in progress on an undescribed Queensland grass formerly thought to belong to *Neurachne*, now thought to be a new genus (with Columbus and Simon).
- *Thysanotus*: fieldwork carried out concentrating on the twining species group and others not yet studied in the field, which has lead to the realisation that the twining group appears to consist of several species instead of two. A new non-twining species was discovered near Ongerup, and a paper drafted describing it.
- Bush Blitz surveys: ongoing work on several new or potentially new species with descriptions and two papers in preparation. Four new species of *Arthropodium* and *Tricoryne* ewxognised as part of the taxonomic reviews of these genera.
- *Leptospermum spinescens* (Myrtaceae): Draft paper not progressed.
- *Brachyloma* (Epacridaceae): A draft paper of a taxonomic revision of a section of the genus is still being edited.
- *Logania* (Loganiaceae): a paper describing a new species from the eastern edge of the jarrah forest was published and another possible new species from the south-west forests is under investigation.

- Preparation of identification aids for cryptogams, especially lichens, for field surveys in the southern forests and jarrah forest; considerable work carried out on an interactive key for lichen genera and a representative collection of photos of Western Australian lichen genera was finalised for review before incorporation into FloraBase.

Management implications

- The conservation status was clarified for several species and an Interim recovery plan prepared for one. Phrase names that were applied to several newly recognised undescribed species enables them to be protected, if required.
- Work in the Muir-Unicup wetlands provides botanical expertise for regional staff, which has resulted in identification of weed threats that are being actively managed; a neglected plant community has been recognised, characterised and understood to be natural rather than degraded; several plant groups are being better collected to improve biodiversity knowledge and to overcome some potential impediments to effective conservation in the area.

Future directions

- Continue to complete and submit papers describing known new species and learn more about 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.

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

SPP# 2011-006

Team member

N Lander (0.4).

Context

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 which are easily confused and have been difficult to distinguish. Also describe a number of new species of *Olearia* and related genera.

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.

Aims

- Taxonomic revision 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 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.
- Treatment of *Olearia* for forthcoming revision *of Flora of South Australia.*

Summary of progress (2010/2011) and main findings

- Interactive key to Western Australian Asteraceae genera (183 genera) extended with further binary keys to species.
- Underlying database completed and extended to include new data available in a recently published monograph of the family. Now complete for all 183 genera present in Western Australia.
- Completed audit and return of *Olearia* loan from Adelaide Herbarium (AD) and audited remaining *Olearia* loans.
- Prepared draft papers describing new species of *Pleurocarpaea* and *Minuria.*

Management implications

- The Asteraceae have a major centre of diversity in Western Australia, with some 583 species (in 183 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 Australia by 125 weedy species, some of critical significance.

Future directions (next 12–18 months)

- Prepare further papers on taxonomy of *Olearia* and several new related genera.
- Submit interactive key to Western Australian Asteraceae Genera for incorporation in FloraBase.
- Complete interactive key to Western Australian *Olearia* species for incorporation in FloraBase.
- Revise treatment of *Olearia* for new edition of *Flora of South Australia*.
- Resolve status of a number of new taxa of Western Australian Asteraceae from the Pilbara (Western Australia), from New South Wales and South Australia and publish new taxa as necessary.

Herbarium collections management

Core function

Team members

K Knight (1.0), K Thiele (0.2), R Cranfield (0.4), R Rees (0.5), C Parker (0.2), P Spencer (0.5), M Falconer (0.6), R Davis (0.8), S Coffey (1.0), A Chapman (0.1), M Hislop (0.9).

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 (2010/2011) and main findings

The herbarium collections management program prepared the collection for the move to the new Herbarium facility in the Western Australian Conservation Science Centre. Programs were either closed or working at a very reduced level, and a comparison with last year's statistics reflect this.

- 3 826 specimens were added to the collection, which now stands at 726 545, a 0.5% increase during the year.

- The major plant groups in the collection are as follows:

Taxonomic Group	Number of specimens (June 2011)	Increase since June 2010	
		Number	%
Myxomycetes	755	1	0.00
Fungi	22 938	111	0.01
Lichens	16 273	5	0.00
Algae	23 073	280	0.03
Liverwort and hornworts	1 961	1	0.00
Mosses	6 676	30	0.00
Ferns and fern allies	3 601	9	0.00
Gymnosperms	2 013	6	0.00
Flowering plants	649 255	3 383	0.46
Total number	726 545	3 826	0.50

Identifications:

- Curatorial work was accomplished in the following groups; Fungi, Myxomycetes, Algae, *Baeckea*, *Acacia, Calothamnus, Tephrosia,* and *Eutaxia.*
- Significant collections added to the Herbarium holdings came from the Greenstone Surveys, Mulga Project, Threatened Flora Seed Centre vouchers, Kings Park, DEC regional offices, regional herbaria, Mornington Sanctuary and a range of environmental consultancies.
- Loans and exchange:
    - Loans outward—4 394 specimens and exchange outward—531 specimens.
    - Loans inward—1 663 specimens and exchange inward—324 specimens
- Volunteer participation was significant, totalling ~ 3 557 hours. This is reduced compared with previous years because of the closure of the volunteer program in preparation for the move of the collection.
- Tasks managed by curation staff with the assistance of volunteers were as follows:
    - mounting and labelling 3 848 specimens
    - general curation of specimens, and incorporation of specimens into the collection
    - auditing the collection.
- Specialist volunteer projects:
    - curating Austrostipa, Eucalyptus, Pterostylis, Verticordia, Calandrinia, Proteaceae and Goodeniaceae
    - capturing and preparing composite images for FloraBase
    - increasing the collection and documentation of *Myxomycota*
    - maintaining and adding specimens to the Reference Collection.
- Maintained and increased the number of taxa represented in the Reference Herbarium which currently has over 14 000 specimens representing c. 11 000 taxa. Over 2 000 visitors used this resource to identify plant specimens during the year.

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 12–18 months)

The move of the collection to the Western Australian Conservation Science Centre and new herbarium facility will provide a challenge to the Herbarium over the next 12 months. A smooth transition with a minimum of disruption will be facilitated by the extensive planning and preparation undertaken.

The Western Australian plant census and Australian Plant Census

Core function

Team members

S Carroll (0.4), C Parker (0.1), T Macfarlane (0.1), U Sirisena (0.2), M Falconer (0.05).

Context

The Western Australian plant census (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 Flora 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. The Western Australian Herbarium is providing substantial input into the APC project through an APC Working Group and membership of the Council of Heads of Australian Herbaria. As the APC project continues, WAcensus is updated to reflect the consensus view.

Aim

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 (2010/2011) and main findings

- A total of 450 new names were added to WACensus, with 4 being new manuscript names, 49 phrase names and 397 being published names.
- A total of 293 other edits were made to WACensus.
- A total of 140 species were assigned priority status in WACensus.
- WACensus updates were regularly distributed to over 400 registered Max users on a monthly basis.
- Major families processed for the APC were Asteraceae, Fabaceae, Myrtaceae, Scrophulariaceae (including *Eremophila*), Dilleniaceae and Stylidiaceae.
- Myxomycota and some fungi groups were added to the census.
- The census was upgraded to support the adoption of APGIII nomenclature and family arrangement.

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 12–18 months)

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

The Western Australian Herbarium's specimen database

Core function

Team members

S Carroll (0.6), M Falconer (0.35), E McGough (0.5).

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.

Aim

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 (2010/2011) and main findings

- 3 826 records were added to the specimen database, including 268 Priority Flora and 61 Declared Rare Flora.
- Thirty eight requests for specimen data (species lists for areas of Western Australia, specimen label data for particular taxa) were processed from DEC offices, researchers and the general public.

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 12–18 months)

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

FloraBase – the Western Australian flora

Core function

Team members

A Chapman (0.6), B Richardson (0.4).

Context

FloraBase, the web information system for the Western Australian flora, has increasingly become 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.

Aim

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.

Summary of progress (2010/2011) and main findings

- Completed integration of the APGIII family classification system.
- Completed integration the *Nuytsia* journal website for presentation within FloraBase.
- Completed testing of a web tool for harvesting online descriptions from *Flora of Australia* volumes.
- Ongoing collaboration with DEC's Eco-Education unit, and regular provision of Plant of the Month content for their state-wide newsletter.
- Ongoing implementation of a staged roll-out of features and improvements as documented in the Herbarium's issues tracking tool (MANTIS).
- Re-evaluation of technology models for content delivery in FloraBase 3 in the light of the federally-funded Atlas of Living Australia project.
- Testing of software as a prelude to the implementation of FloraBase 3.

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 13 430 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.

Future directions (next 12–18 months)

- Implementation of the third major version of FloraBase.
- Deliver taxon descriptions from a range of sources, firstly the online *Flora of Australia*.
- Add new content, including interactive keys for identification of plant groups at species level.
- Add further standards support to allow FloraBase to participate in national and international bio-infrastructure projects, such as consuming web services from the Atlas of Living Australia.
- Maintain the quality of information and the adequacy of software and hardware systems.

Biodiversity Informatics at the Western Australian Herbarium

Core function

Team members

A Chapman (0.1), B Richardson (0.2).

Context

DEC's Science Division databases contain a large amount of quality biodiversity data. For some of these databases, there is no means of access other than direct to the database itself. DEC can better promote the understanding of Western Australia's natural biodiversity by providing access to this data through web services. The most important method of providing access to biodiversity information is through the use of data standards created by 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.

Aim

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

Summary of progress (2010/2011) and main findings

Commenced preliminary analysis of the suitability of a reimplementation of WAHerb in Specify 6.

Management implications

- 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 biodiversity informatics tools will further aid efficiencies in flora management within the state.

Future directions (next 12–18 months)

- Implement use of image collection management software and conduct training to Herbarium staff and volunteers.
- Complete the preliminary analysis of the suitability of a reimplementation of WAHerb in Specify 6.
- Continue the integration of FloraBase and NatureMap to identify and build shared software components.
- Collaborate with national and international bodies in the definition of standards for biodiversity information.
- Collaborate in projects that simplify the use of biodiversity information in the online context, e.g. co-authorship of software that our clients can download and use.

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 (0.8), C Parker (0.1) .

Context

This project involves systematic research into a poorly known group of Western Australian plants and is directly relevant to DEC's nature conservation strategy. It includes floristic studies of the marine plants of several existing/proposed marine parks and also areas of commercial interest (Ningaloo, Dampier Archipelago, Barrow Island, Montebello Islands, Rowley Shoals, Scott Reef, Maret Islands, etc.). In addition, the general floristic surveys will 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 Flora for north-western Australia, documenting this biodiversity.

Summary of progress (2010/2011) and main findings

- Continued generation of descriptions and illustrations for the '*Marine Benthic Flora of north-western Australia*. This book will include over 400 species, many of which are new to science, and each will be fully illustrated.
- New collections made from Barrow Island and the north Kimberley (Cassini Island and Long Reef) have included several new taxa, which will be included in the '*Flora*', and contributed several hundred specimens to the Herbarium.
- Major papers concerning the typification of an important historical collection of Western Australian algae (by Irish botanist WH Harvey), the marine flora of the Walpole/Nornalup Marine Park, and revisions to red algal family Liagoraceae have also been published.

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 12–18 months)

- Publication of papers describing new and existing genera, species and other categories; contributions to FloraBase.
- Finalise production of an 'Algae of Australia' Flora covering the marine plants of north-western Australia.

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 (0.2), C Parker (0.2).

Context

This project is a direct successor to the 'Western Australian Marine Plants Online'. It will provide descriptions of the entire Western Australian marine flora as presently known, accessible through FloraBase. In addition, an interactive key to the genera is in preparation that will enable positive identification of specimens and provide a baseline marine Flora for future revisions. This project will provide a user friendly resource that will enable 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 600 genera of Australian marine macroalgae.
- Provide online descriptions of the Western Australian marine flora as presently.

Summary of progress (2010/2011) and main findings

- Close to 900 species descriptions (including approx. 100 newly written) have been edited, standardized and uploaded to FloraBase. Genus descriptions for taxa occurring in Western Australia have been prepared and are being finalized before uploading.
- Fact Sheets including descriptions and images have been prepared for the 600 genera to be included in the interactive key. Characters and character states are being added to the key database.

Management implications

- Easier identification of marine plant species will lead to a more accurate understanding of their conservation status.
- 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 12–18 months)

- Complete coding of Lucid software key.
- Continue collating existing species descriptions (where available) and write new descriptions for uploading to FloraBase.
- Upload additional marine plant images to FloraBase.

Perth Urban Bushland Fungi (PUBF) project

SPP# to be allocated

Team member

N Bougher (0.2).

Context

Knowledge of the fungi and other cryptic organisms that help keep the region's plants healthy is essential for effective conservation management of Perth's bushlands. This project has developed protocols to foster community participation and education while simultaneously capturing scientific data about fungi. PUBF is raising the previously low level of awareness and knowledge about fungi and encouraging the inclusion of fungi in bushland management.

This is a collaborative project between the Western Australian Naturalists' Club, the Perth Urban Bushland Council, and the Western Australian Herbarium.

Aims

- Promote a better understanding of the significance of fungal diversity and function in bushlands.
- Generate and provide access to scientifically accurate information about fungi of the Perth Region.

Summary of progress (2010/2011) and main findings

- Conducted five workshops and forays in urban bushlands.
- Produced foundation fungi inventories for additional bushlands.
- Recorded 267 fungi and processed and vouchered about 100 fungi specimens.
- Produced six fungi reports.
- One hundred new fungi species names from the book *Fungi of the Perth Region and Beyond* were added to WACensus, with consequent flow into Florabase.

Management implications

- Perth's urban bushlands are an important natural refuge for many fungi. Fungi underpin the long-term health and resilience of the bushlands.
- Knowledge of the fungi and other organisms that help keep the region's plants healthy is essential for effective conservation management of this biodiversity hotspot.

Future directions (next 12–18 months)

- Conduct at least three public field events (forays and workshops), two contracted surveys, and assist in the organization and running of the FungiMap VI conference to be held in Western Australia.
- Further incorporation of PUBF fungal specimen data and species images into databases.
- Input PUBF data into WACensus and FloraBase or similar taxa-based online information system.

Improving the comprehensiveness, accuracy and availability of taxonomic data about Western Australia's fungi in DEC biological datasets and biodiversity collections

SPP# to be allocated

Team member

N Bougher (0.4).

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 (2010/2011)and main findings

- Completed a nomenclatural revision of the only previously published census of Western Australian macrofungi.
- Submitted 604 new fungi names for addition to WACensus.
- Identified and submitted 5 030 edits for Western Australian Herbarium database and vouchers.
- Published journal papers including defining a new species of ammonia fungus from Western Australia, and documenting over 100 new records of fungi/slime moulds at Kings Park.
- Completed and reported two fungi research surveys for external client.
- Promoted access and uptake of fungi scientific knowledge; including completing five community biological surveys, delivering six invited seminar/workshop talks, and responding to numerous public inquiries.

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 12–18 months)

- Focus on taxonomic research and publication outputs defining and documenting fungi of the ectomycorrhizal fungi family Inocybaceae.
- Complete and submit publication contributing to the census of Western Australian macrofungi.
- Generate and provide descriptive and identification data for key fungal species.
- Continue addition of descriptive fungi data into FloraBase or similar taxa-based online information system.

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

SPP# 2011-014

Team member

K Thiele (0.1).

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 to 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 (2010/2011) and main findings

- A paper describing a new, rare species of *Darwinia*, *D. hortiorum*, has been published in *Nuytsia*.
- A paper describing a new, rare species of *Hibbertia*, discovered during biological surveys of the greenstone belts of the Goldfields, is has been completed for submission to *Nuytsia*.
- A short communication resolving the taxonomic status of an informally named rare orchid, *Epiblema grandiflorum* var. *cyaneum* ms and recommending its removal from the Western Australian Census and Declared Rare Flora schedule has been published.
- A paper resolving the high-level phylogeny of the Poales (the group containing grasses, orchids, lilies and many other monocotyledonous families) has been published.

Management implications

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

Future directions (next 12–18 months)

Work on the taxonomy of *Hibbertia* (Dilleniaceae) has made it clear that many undescribed species remain in the genus. Resolving and describing these will be a principal focus for this project.

Development of interactive identification platforms and content

SCP# 2007-014 (SPP# to be allocated)

Team members

K Thiele (0.1). Volunteer: C Hollister (0.4).

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.

Aim

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

Summary of progress (2010/2011) and main findings

A key to species of the important family Goodeniaceae has been coded and made available for testing and use by members of the community, particularly consultants.

Management implications

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

Future directions (next 12–18 months)

- Continue development of the key to Goodeniaceae, correcting errors and making improvements provided from user feedback, and ready the key for final formal publication.
- Improve and revise images for the Proteaceae keys and ready the keys for final formal publication.

Surveys, systematics and genetic diversity of granitic and sandstone vernal pools flora

SPP# to be allocated

Team member

M Moody (0.2).

Context

The granite outcrop vernal pools (gnammas) are one of the highly unique ecosystem to Western Australia and perhaps one of the most threatened by global climate change. Yet, these systems have received little attention and their biodiversity and ecology is poorly known. Several of the more conspicuous plants of the vernal pools have been recognised as priority or rare flora, with less conspicuous plants poorly known. A comprehensive plant survey and genetic study of these systems will provide an understanding of their diversity, composition and is likely to lead to the discovery of cryptic species. Population level genetic studies of rare species in the system will provide information on genetic diversity in populations and gene flow among populations to assess the immediate threat these species may face due to loss of habitat.

Aims

- Determine the plant diversity in the granitic vernal pools of south-western Australia.
- Apply molecular tools to identify cryptic species or subspecies (unique lineages) among the often inconspicuous and difficult to identify aquatic plants and develop a DNA barcode for the rare and priority species of the gnammas.
- Examine the genetic diversity of rare and/or priority species in this system and compare with more common plants.
- Survey ecological factors that are important to these systems.

Summary of progress (2010/2011) and main findings

- Analyses of nuclear DNA suggests taxonomic revision of Western Australian *Glossostigma* will be necessary. A much wider distribution than currently known for *Glossostigma trichodes* means recommendation for alternative conservation designation will be made. Several distinct lineages of *Isoetes* have been recognised using nrDNA ITS and collections from granite pools. *Isoetes brevicula* is clearly delimited from other granite pool endemics. *Isoetes inflata*, *I. caroli* and *I. australis* are distinguished, but more lineages have also been discovered. The granite pool species of the southwest appear to be monophyletic and distinct from *I. muelleri* and *I. drummondii*, not found in granite pools. Comparative phylogeography based on these data sets and those of the distribution patterns of *Myrioplyllum petraeum* is being conducted.
- Rare genotypes for all taxonomic groups were found on specific granite outcrops in the Northam region.
- Complete data sets of cpDNA and ITS for *Myrioplyllum petraeum* have been constructed and analysed with strong regional divergence discovered. Unique genotypes were found at 10-12 populations sampled. The matK cpDNA region is being added to date the divergence among lineages more accurately against the family level phylogeny. Deep divergence was uncovered among three distinctive lineages. Fruit morphology will distinguish southern lineage from northern lineages. A higher conservation ranking for newly recognised lineages will be recommended.
- Species level markers do not detect variation among populations of the rare species *Myrioplyllum lapidicola*.

Management implications

Identification of unique lineages and rare species will lead to better, more targeted conservation plans. For example identification of specific lineages in *Myrioplyllum petraeum* specific means that these lineages should be targeted for conservation rather than treating all populations equally. The vernal pools are under particular threat due to global climate change and weeds, especially those reaching through the wheatbelt and into more arid zones of the south-west.

Future directions (next 12–18 months)

- Complete analyses of *Myrioplyllum petraeum* data and collect data from an additional cpDNA *matK* region.
- Complete collection of molecular data from species of *Glossostigma*, *Isoetes* and *Crassula* to complete comparative analyses.
- Analysis of data and publication of results.

New tools to uncover a *Eucalyptus* phylogeny and evaluate conservation priority species

SPP# to be allocated

Team member

M Moody (0.2).

Context

Eucalyptus is species rich genus with many taxa of conservation concern (including 35 species/subspecies in the south-west Western Australian groups *Hadrotes* and *Glandulosae* alone). Within *Eucalyptus* species boundaries can sometimes be vague and subspecific designation is often employed. Most species are described using morphology alone, but more frequently molecular methods are being employed to evaluate species limits across all organisms, especially among traditionally difficult taxonomic lineages. Given that conservation management uses 'species' as the primary measure of biodiversity, rigorous methods for species hypothesis testing are crucial. Newly developing methods to evaluate species hypotheses in systematics include phylogenetic or haplotype-network analyses using DNA sequence data, which requires data with high variability from both chloroplast and nuclear DNA sources, not currently available for *Eucalyptus*. This research will develop and test nuclear DNA intron sequence markers for variability at the species level among Western Australian taxa.

Aims

- Develop nuclear DNA intron sequence markers that are phylogenetically informative at the species level and transferable across *Eucalyptus* using the Expressed Sequence Tag (EST) library for *Eucalyptus grandis*.
- Evaluate the utility of these markers through a phylogenetic analysis of the south-west Western Australia endemic *Eucalyptus* subsection *Hadrotes* and a selective sampling of *Glandulosae* and a sampling across all subgenera and several sections.
- Evaluate the utility of two chloroplast DNA intron markers for which high variability has recently been described across taxa evaluated using the nuclear markers.

Summary of progress (2010/2011) and main findings

- Issues with polymorphism have made sequence editing challenging for most species of *Eucalyptus* subsection *Hadrotes.* An effort to clone several sequences will be needed to make progress.
- Chloroplast DNA sequences and nrDNA ITS have been collected for all species and comparisons of variability and phylogenetic topology are being made.

Management implications

Development of these markers and their apparent utility at the species level is promising for use across *Eucalyptus* lineages for systematic studies evaluating species/subspecies hypotheses. These markers can potentially be used for species and hybrid identification and determining phylogeographic patterns.

Future directions (next 12–18 months)

- Sequence clones of selected regions and taxa.
- Complete collection of sequence data for the nuclear markers and test amplification across a wider set of *Eucalyptus* species.
- Complete analyses of variability of genes across all taxa, complete phylogenetic analyses of the *Hadrotes* group and evaluation of current species and subspecies limits of subsection *Hadrotes*.

Systematics of the triggerplant genus *Stylidium*

SPP# 2010-001

Team Member

J Wege (0.9).

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 more than 60 taxa are listed as Declared Rare Flora or Priority Flora, the majority of which require further survey to understand the full extent of their distribution.

Aim

Improve the underlying taxonomic knowledge necessary for effective biodiversity management of the triggerplant genus *Stylidium* and to make this information readily accessible to stakeholders. This will be achieved through the resolution of the taxonomy, nomenclature and conservation status of each taxon, and the creation of an electronic key and species fact sheets. The current project focus is taxa occurring in southern Australia.

Summary of progress (2010/2011) and main findings

- Field work targeting the ephemeral species was conducted in the south-west of Western Australia, on Kangaroo Island (South Australia), and in the Grampians National Park (Victoria). Drought conditions throughout the south-west region severely impacted this research since many populations failed to flower, or flowered poorly. Nonetheless, sufficient collections and data were obtained to advance or complete taxonomic research on several species complexes. Photographs of a range of species were captured for inclusion in the interactive key and FloraBase, and vouchers for ongoing phylogenetic studies were collection. Several new populations of poorly known species were discovered.
- A taxonomic revision of the ephemeral triggerplants from southern Australia (*Stylidium despectum* and allies) was completed and submitted for publication. This paper includes the description of a new and potentially rare triggerplant, and a comprehensive nomenclatural review that presents new circumscriptions for both *S. despectum* and *S. inundatum*.
- A paper describing five taxa from south-west Western Australia and reviewing the typification of 24 taxa was published in *Nuytsia*, and substantial progress made on a second typification paper. A co-authored treatment of Stylidiaceae was published in the *Flora of China*.
- Progress has been made on compiling species fact sheets for inclusion in the interactive key and on FloraBase.

- The identity of herbarium specimens at the Western Australian Herbarium and other national and international institutions continues to be confirmed or corrected.
- Measurement data was generated for an ongoing collaborative pollination study.

Management Implications

The publication of names, scientific descriptions and associated data for a range of new taxa improved understanding of the distribution, habitat requirements and conservation status of triggerplant species and will facilitate their conservation and management.

Future Directions (next 12 months)

- Conduct field studies and complete taxonomic papers on focus groups.
- Progress interactive key and fact sheets.
- Conduct further collaborative pollination studies and advance molecular phylogenetic research.

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

SPP# to be allocated

Team member

R Davis (0.2).

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 in the genus *Ptilotus*.
- Review infraspecific taxa within *Ptilotus.*
- Create interactive keys to all Western Australian species of *Ptilotus*, *Gomphrena* and *Swainsona*.
- Publish new taxa in other genera.

Summary of progress (2010/2011) and main findings

- Two papers published for *Nuytsia* dealing with infraspecific taxa in *Ptilotus stirlingii* and *Ptilotus polystachyus*.
- One paper pending in *Nuytsia* dealing with the infraspecific taxa in *Ptilotus humilis*.
- Descriptions of *Ptilotus* for the *Flora of Australia* treatment almost completed.
- Draft interactive keys to *Ptilotus*, *Gomphrena* and *Swainsona* continuing.
- Submission of paper on infraspecific taxa within *Adenanthos pungens*.
- Submission of paper on infraspecific taxa in *Ptilotus*.
- Submission on a new species of *Ptilotus* from the Swan Coastal Plain.

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 12–18 months)

- Completion of descriptions of *Ptilotus* for the *Flora of Australia* treatment.
- 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 Lucid keys to *Ptilotus*, *Gomphrena* and *Swainsona*.
- Paper on a new species of *Grevillea* from the Great Victoria Desert.

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

SPP# 2011-015

Team members

M Hislop (0.2), A Chapman (0.05), K Thiele (0.05).

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 (2010/2011) and main findings

- One paper published in *Nuytsia*—one new apparently rare species of *Acrotriche* was described. Three further papers submitted to *Nuytsia* in which four new *Leucopogon* taxa, a new *Monotoca* and three new *Dielsiodoxa* are described. Updated descriptions are also provided for another four taxa. Eight of the taxa treated in these papers are of conservation concern.
- Four phrase-named taxa were added to the *Western Australian Plant Census* as a result of ongoing taxonomic study. One species was also reinstated.
- Two taxa were added to the Declared Rare and Priority Flora list for Western Australia.
- 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* comprises 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 12–18 months)

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

LANDSCAPE CONSERVATION

PROGRAM LEADER: DR LACHLAN 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.

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

SPP# 2006-003

Team members

R Robinson (0.25), L McCaw (0.2), J Farr (0.25), K Whitford (0.3), R Cranfield (0.2), G Liddelow (0.2), V Tunsell (0.8), B Ward (0.2), A Wills (0.2), P Van Heurck (0.1).

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.

Aim

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 (2010/2011) and main findings

- Ten grids in Wellington 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 2009-2010 annual report for grids in the Perth Hills District was completed. Findings were presented at Kensington in October 2010.
- Nine papers presenting results of analysis from the first five years of monitoring are in press, and a synthesis paper is nearing completion.
- Forest Products Commission staff were briefed on the results from the first five years and subsequent progress at Manjimup in November 2010.
- Results of the project were also presented at the Australian Mycological Conference in Sydney in July 2010 and to the Western Australian Naturalists' Club in Perth in March and May 2011.

Management implications

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

Future directions (next 12–18 months)

- A consolidated body of scientific papers on the findings of the project will be published.
- Findings will be presented to the expert panel convened for the review of silvicultural practice.
- Additional monitoring grids will be established in examples of forest harvested under SFM Guideline No.1, 2004, *Silvicultural Practice in the Jarrah Forest*.

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 (0.15), B Ward (0.2), R Cranfield (0.05), G Liddelow (0.1).

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 southern jarrah forest understorey.
- Determine the effects of different fire regimes on tree health and growth rate.

Summary of progress (2010/2011) and main findings

- Plant species richness and composition were assessed at Perup and McCorkhill sites.
- Spring and autumn burn treatments were applied at the Perup and McCorkhill sites.

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 (~700 mm 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 12–18 months)

- Maintain fire treatments at all study sites.
- Measure and analyse tree growth—McCorkhill forest.
- Analyse all data on the effects of various fire regimes on understorey vegetation and prepare a paper for publication.

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 (0.15), D Algar (0.05), G Liddelow (0.15), B Ward (0.05), N Hamilton (0.1), M Onus (0.1). External: Goldfields Regional staff (0.2), Prof T Bragg (University of Nebraska, Omaha).

Context

Despite the relatively pristine nature of most of the arid interior (desert bioregions) and rangelands (beyond the pastoral zone), there has been an alarming and recent loss of mammal fauna with about 90% of medium-size mammals and 33% of all mammals either becoming extinct or suffering massive range contractions. There is also evidence of degradation of some floristic communities due to altered fires regimes. The extent and nature of change in other components of the biodiversity, including extant

mammals, birds, reptiles and invertebrates is unknown. The most likely causes of the decline and degradation in biodiversity are introduced predators, especially the fox (*Vulpes vulpes*) and the feral cat (*Felis catus*), and altered fire regimes since the departure from traditional Aboriginal burning practices over much of the region. Taking an adaptive experimental management approach in partnership with 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 (2010/2011) and main findings

- A successful feral cat, fox and wild dog aerial baiting and trapping operation was carried out again in 2010 as part of the Western Shield program. Introduced predators were successfully removed from the 1 100 ha acclimatisation compound.
- Quarterly predator surveys were carried out. Feral cat track activity remains low with the track density index (TDI) 7-11.4 (from a pre-treatment high of >30). A draft manuscript summarising introduced predator work at Lorna Glen over the past six years has been prepared for publication.
- Biodiversity monitoring sites (BioMonitoring) were re-assessed. Although species diversity was high, capture rates were down on previous assessments, probably due to prolonged dry conditions.
- With the expiry of the old plan, a new fire management plan was prepared, which focuses on buffer burning and mosaic (patch) burning.
- The 1 100ha predator-proof acclimatisation compound has proven to be highly successful. There have been no predator breaches and animals in the compound are thriving.
- A trial using observers on horseback to monitor bilby activity was successfully completed.

Management implications

- 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 12–18 months)

- Implement and assess the effectiveness of a seventh annual feral cat and fox baiting program.
- Reintroduce bilbies and another two native mammal species.

- Continue to monitor extant fauna and vegetation (biomonitoring sites).
- Continue assessment of vascular plants and invertebrates.

Burning for biodiversity: Walpole fine grain mosaic burning trial

SPP# 2004-004

Team members

N Burrows (0.05), J Farr (0.1), R Robinson (0.1), G Liddelow (0.1), B Ward (0.25), R Cranfield (0.05), V Tunsell (0.1), P Van Heurck (0.1), A Wills (0.1). External: 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. Specifically the project will investigate:
    - the abundance of fire regime specific plant taxa, Declared Rare Flora and priority listed taxa (e.g. *Synaphaea* sp., *Lambertia rariflora* subsp. *lutea*, *Banksia quercifolia*, *B. occidentalis*, *B. formosa*, *Hakea oliefolia*) under this fire regime;
    - abundance of fire regime specific fauna and condition of associated habitats including honey possum (*Tarsipes rostratus*), quokka (*Setonix brachyurus*), mardo (*Antechinus flavipes*), sunset frog (*Spicospina flammocaerulea*), reptile assemblages, bird assemblages, invertebrate assemblages, vascular plant, fungi and cryptogam assemblages.
- 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 (2010/2011) and main findings

- Biodiversity monitoring sites were re-assessed.
- Data emerging from the invertebrate and macrofungi studies in particular are suggesting that species diversity is enhanced in a landscape of diverse seral stages.
- Fuel age mosaic maps were constructed from satellite imagery.
- *B. quercifolia* sites were re-assessed. Although this species is characterised as fire sensitive, the study population has persisted under several short interval (2-3 years) prescribed burn cycles because under the mild burning conditions and sparse fuels the population did not burn whereas other more flammable fuel types did burn.

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 12–18 months)

A review meeting will be held in July 2011 to assess progress and determine the future of the project.

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

SPP# 1998-007

Team members

M Byrne (0.2), B Macdonald (0.5), D Coates (0.1), S van Leeuwen (0.1), S McArthur (0.1).

Context

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

Aim

Provide genetic information for the conservation and utilisation of plant species for revegetation and rehabilitation. Current work aims to identify the mating system and population relationships of *Acacia saligna*; investigate the mating system and diversity in sandalwood, determine genetic relationships between trees in a salinity/waterlogging trial in *Eucalyptus occidentalis*, and identify seed collection zones for species used in rehabilitation of minesites in the Pilbara.

Summary of progress (2010/2011) and main findings

- *Acacia saligna*—A journal paper on the structure of genetic differentiation among populations has been published.
- *Santalum spicatum*—Genotyping of samples from 15 natural populations has commenced.
- *Eucalyptus occidentalis*—Journal paper on effect of genetic distance on progeny performance has been published in *Silvae Genetica*.
- *Eucalyptus leucophloia*—Collections were made from 20 populations across the Pilbara bioregion and genetic analysis was conducted using microsatellite markers. Genetic diversity was high as is typical of eucalypt species with wide spread distributions. Across the species the level of population differentiation was low and the majority of the diversity was maintained within populations with only 6% of variation partitioned between populations. Genetic variation showed little structure across the Pilbara with no clustering of populations based on geographical proximity or in association with obvious topographical, physiogeographical or geological features. A report was prepared for Rio Tinto.
- *Acacia ancistrocarpa* - Collections were made from 24 populations across the Pilbara bioregion and genetic analysis was conducted on 16 populations using microsatellite markers due to some difficulty in extracting high quality DNA from all populations. Genetic diversity was high but lower than that in *E. leucophloia*. Across the species the level of population differentiation was low and the majority of the diversity was maintained within populations with only 3% of variation partitioned between populations. Genetic variation showed little structure across the Pilbara with no clustering of populations based on geographical proximity or in association with obvious topographical, physiogeographical or geological features. A report was prepared for Rio Tinto.

Management implications

- *Acacia*—Several genetic and evolutionary lineages have been identified in both *A. microbotrya* and *A. saligna*. The level of differentiation between the lineages will support and inform taxonomic revisions of these two complexes. Clarification of the taxa within these complexes will enable development for revegetation plantings to be carried out in a reliable manner without risk of genetic contamination and hybridisation in natural populations.
- *E. Occidentalis*—Improved survival of progeny from wide crosses under saline conditions and low genetic structure among families implies breeding with salt and/ waterlogging tolerant individuals would result in substantial increases in salt and/ waterlogging tolerance, but no decline in genetic diversity.
- Pilbara seed collection zones—The high levels of genetic diversity and low levels of differentiation within *E. leucophloia* and *A. ancistrocarpa* implies that seed resources for land rehabilitation and mine-site revegetation programs can be selected from a wide distributional range within the Pilbara,

thus maintaining genetic diversity of restoration areas. It is recommended that seed collections be focussed within the same Pilbara biogeographical sub-regions as the disturbance site to ensure limited mixing of seed between sub-regions.

Future directions (next 12–18 months)

- Journal paper describing genetic diversity in *A. microbotrya* will be written.
- Genetic diversity will be investigated in two more species in the Pilbara.

Identification of seed collection zones for rehabilitation

SPP# 2006-008

Team members

M Byrne (0.1), D Coates (0.1), S McArthur (0.5).

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 on an ecologically sustainable fashion. This requires an understanding of the genetic structure and local adaptation of species.

Aim

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 (2010/2011) and main findings

- Preliminary analysis of genotype data of *Kennedia coccinea* shows little genetic structure throughout the forest region.
- Leaf material has been collected from 20 individuals of 24 populations of *Allocasuarina humilis* and DNA extractions have been completed. A microsatellite library has been developed and testing of variable microsatellite markers is currently underway.

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.

Future directions (next 12–18 months)

- Further data analysis undertaken for *Bossiaea ornata*.
- Genetic analysis of *K. coccinea* will be completed.
- Genotyping of *A. humilis* will be undertaken.

Management of environmental risk in perennial land use systems

SPP# 2004-003

Team members

M Byrne (0.2), C Munday (0.6), J Sampson (0.6), K Bettink (0.4).

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 (2010/2011) and main findings

- Weed risk assessments were completed for 20 exotic and native forage and woody species and are published on line at the FFI CRC website: two assessments are awaiting publication on the new website and a further four are in draft.
- Genetic risk assessment protocol was developed and journal paper written and submitted to *Journal of Applied Ecology*. The protocol is published on the FFI CRC website.
- Continued involvement in national discussions on improvements to border and post-border weed risk assessment.
- Journal paper on comparative assessment of weed risk protocols was published in *Plant Protection Quarterly* and paper entitled 'The 'duty of care' in introducing new plants for agriculture' has been published in *Current Opinions in Environmental Sustainability*.
- Data analysis for research study investigating flower: fruit production in variants of *Acacia saligna* under common environmental conditions is in progress.
- Data analysis of the impact of the exotic species *Plantago lanceolata* on regeneration of native flora following a fire is in progress.
- Journal paper on the genetic structure in *Atriplex nummularia* and genetic differentiation between subspecies has been written and submitted for publication.
- Format for species management guide for land holders was finalised and the guides for the first two species were published on the FFI CRC website. Two additional guides are in final preparation for publication and a further two are in draft.
- A field trial registration form has been developed and incorporated into the annual reporting process.
- Guidelines for management of experimental trial sites have been completed. Guidelines were presented to the CRC Postgraduate Professional Development Conference in August 2010.

Management implications

- Introduction of weed risk management and culture into the FFI CRC will reduce the risk of large-scale plantings of new perennial species or newly developed cultivars becoming environmental weeds.
- Knowledge of gene flow will enable the risk of genetic contamination and hybridisation to be assessed and lead to development of risk management guidelines.

Future directions (next 12–18 months)

- Implement the genetic risk assessment protocol within the FFI CRC.
- 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*.
- Write paper on genetic identification of weedy populations of *A. saligna*.

State Salinity Strategy wetland monitoring

SPP# 1998-018

Team members

A Pinder (0.1), D Cale (0.4), A Leung (0.1), M Lyons (0.25), C McCormick (0.75), J Lane (0.4), A Clarke (0.8), Y Winchcombe (0.4), B Muir (0.05).

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. Broadscale 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 monitoring project.

Aim

Monitor changes in biodiversity, surface water quantity and quality, and groundwater levels at representative wheatbelt wetlands in relation to increasing dryland salinity and land-use changes to provide information that will lead to better decision-making.

Summary of progress (2010/2011) and main findings

- Fauna monitoring—field component of 2010 monitoring completed, invertebrate dataset being incorporated into comprehensive reports on data collected between 1997 and 2009. Samples from some low priority wetlands were archived to allow new wetlands of higher conservation value and/or management interest (in Drummond and Marchagee Recovery catchments) to be included in the project. Invertebrate data for the Drummond wetlands have been used to set biodiversity targets for the catchment.
- 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 2010 completed.
- Reporting—Report presenting 1977-2008 depth, salinity and pH data for 101 currently-monitored wetlands completed. Report on multi-decadal changes in waterbird use and habitat condition at selected wetlands completed.

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 has provided an understanding of the range of variation in biotic communities under different climates, providing a context against which to assess and predict future changes.
- Surface water management is as important in some wheatbelt wetlands (eg. Coomalbidgup Swamp) as groundwater management in maintaining wetland health and greater focus on surface water is required.
- Knowledge of the salinisation effects of rising groundwater and declining rainfall enables prioritisation of conservation efforts in south-west wetlands.

Future directions (next 12–18 months)

- Subject to adequate winter 2011 rainfall, undertake a study of the changes in invertebrate communities during a winter-spring hydrological cycle in the claypans of the Drummond Nature Reserve.
- Produce 1977–2011 annual SWWMP report during the 2011/2012 financial year.
- 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.

- Undertake bathymetric surveys of SWWMP monitored wetlands on an opportunistic basis.
- Continue continuous water level and rainfall monitoring at selected high value SWWMP wetlands under threat as a precursor to hydrological modelling.

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

SPP# 2006-002

Team members

A Pinder (0.15), A Leung (0.4), M Pennifold (0.7).

Context

Key Performance Indicator 20 of the *Forest Management Plan 2004-2013* requires that aquatic macroinvertebrates be monitored in a selection of streams to provide information on trends in aquatic biodiversity across the forest, particularly in relation to logging and associated forest management activities. It is intended that there be no widespread or sustained decline in aquatic biodiversity as a result of land management practices.

Aim

Monitor richness of aquatic macro-invertebrate families, and species richness within selected orders, at over 50 sites in the jarrah and karri forest each spring.

Summary of progress (2010/2011) and main findings

- Sixth annual round of sampling was conducted in spring 2010 under conditions of very low flow. A number of streams were dry.
- Annual logging and fire histories of all 50 catchments were updated in a GIS environment for the period from 2000 to 2010.
- A major report summarising findings of the first four years of monitoring was approved for distribution.

Management implications

There is very little evidence that current logging and fire management practices in forest catchments have a significant effect on downstream aquatic invertebrate communities.

Future directions (next 12–18 months)

- Identify invertebrates from the 2010 sampling.
- Undertake stream sampling in spring 2011.
- Continue to update fire and logging history within catchment areas.

Bushfire Cooperative Research Centre Project 1.4: Improved methods for the assessment and prediction of grassland curing

SPP# 2007-007

Team member

L McCaw (0.05).

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 (2010/2011) and main findings

- A final project report has been prepared and circulated by the Bushfire Cooperative Research Centre.
- A paper describing the use of a relativeness greenness index for assessing curing of grasslands was published in *Remote Sensing of Environment*.

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 12–18 months)

- Evaluation and testing of curing products provided by the Bureau of Meteorology will continue.
- The project will be finalised and the SPP will be closed.

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

SPP# 2000-003

Team member

J Kinal (1.0).

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—1 100 mm/yr) of the jarrah forest to protect water quality.

Aim

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

Summary of progress (2010/2011) 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 peak groundwater response, relative to the control catchment, was about 2 m in the intensive-treatment catchment and about 1.6m in the standard-treatment catchment.
- A paper describing the comparative hydrological response to two different intensities of timber harvesting and silvicultural treatment was published in the *Journal of Hydrology*.

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.
- These results form the basis of a discussion paper that is proposing changes to management of salinity in salt-sensitive forest in the next Forest Management Plan.

Future directions (next 12–18 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.
- Complete a paper currently in preparation describing the effect of declining groundwater levels on streamflow generation and stream salinity in the jarrah forest.
- 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.

Management of the Vasse-Wonnerup wetlands

SPP# 1999-017

Team members

J Lane (0.2), A Clarke (0.1), Y Winchcombe (0.1).

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 (2010/2011) 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 2010/2011.
- 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 12–18 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.

Monitoring post-fire effects from the 2001 Nuyts wildfire

SPP# 2006-001

Team members

G Liddelow (0.05), B Ward (0.05), R Cranfield (0.05), P Van Heurck (0.01), L McCaw (0.05). 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.

Aim

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

Summary of progress (2010/2011) and main findings

- Data on tree mortality, eucalypt regeneration, shrub regeneration and bird population responses are being analysed and prepared for publication.
- A manuscript examining recruitment of eucalypt seedlings following the 2001 fire has been prepared.

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 12–18 months)

Manuscript will be submitted for scientific publication.

Long-term monitoring of impact of timber harvesting on bird populations in south-west forests

SPP# 1994-008

Team Members

I Abbott (0.01), G Liddelow (0.01), C Vellios (0.01), V Tunsell (0.01), M Williams (0.01).

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.

Aim

Quantify the effects of timber harvesting and silvicultural practices in karri and jarrah forests on birds.

Summary of progress (2010/2011) and main findings

- No field work took place on the project during 2010/2011.

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 12–18 months)

- Counts are scheduled for the Kingston plots in 2011 (15 years after regeneration).
- Resources permitting, eight plots in karri forest established and studied in 1981/1982 by Alan and Sue Tingay will be relocated, permanently marked, and censused for birds. The regenerated forest on the four logged plots is now 26–77 years old, and this range of ages will help complement the information already obtained from Gray forest block (21-year-old regeneration, 120–250 year old mature karri forest).

Project Vesta – prediction of high intensity fire behaviour in dry eucalypt forest

SPP# 1997-003

Team member

L McCaw (0.3).

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 (2010/2011) and main findings

- A paper describing the fuel moisture prediction module of the fire behaviour guide was published in the *International Journal of Wildland Fire*.
- A paper quantifying fuel dynamics in dry eucalypt forest was published in *Forest Ecology and Management*.
- A manuscript detailing flame temperature and residence time during bushfires in dry eucalypt forest has been accepted for publication in the *International Journal of Wildland Fire*.

- A manuscript describing how fire behaviour changes as fuels increase with age has been submitted for publication

Management implications

Fire managers will be provided with the best available tools to predict fire behaviour to achieve prescribed burning objectives and safe wildfire suppression.

Future directions (next 12–18 months)

Finalise publication of scientific papers on fire behaviour experiments and fire behaviour prediction.

Increasing productivity of karri regrowth stands by thinning and fertilising

SPP# 1993-106

Team member

L McCaw (0.05), J Geisel (0.2).

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.

Aim

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 macronutrients and trace elements and coppice control.

Summary of progress (2010/2011) and main findings

- Part of the thinning experiment in 40 year-old karri regrowth forest at Warren block was re-measured.
- Data from thinning experiments at Treen Brook, Warren and Sutton forest blocks were made available for validation of tree growth models in conjunction with timber yield assessment for the revision of the Forest Management Plan.

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 12–18 months)

Re-measurement of the Warren experiment will be completed in 2011/2012 in readiness for second thinning treatment of some plots.

Espacement effects on the development and form of regrowth karri stands

SPP# 1993-107

Team member

L McCaw (0.05), J Geisel (0.3).

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 ha 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.

Aim

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 (2010/2011) and main findings

- A spacing trial established at Nairn forest block in 1982 was re-measured.
- Data from spacing trials at Nairn and Wheatley were validated and analysed to determine the effects of spacing on tree and stand growth, and branching characteristics.

Management implications

Current guidelines for planting density in regenerated karri stands appear soundly based, and initial planting densities above 3 000 stems per ha do not appear to confer any significant improvement in the form of dominant or co-dominant trees.

Future directions (next 12–18 months)

Prepare a manuscript comparing survival, growth and form of planted karri using data from Nairn and Wheatley forest blocks.

Fire induced mosaics in semi-arid shrublands and woodlands

SPP# 1993-086

Team member

L McCaw (0.1).

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 which 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 (2010/2011) and main findings

- A paper examining spatial controls on bushfire frequency was published in the *Journal of Biogeography*.
- A paper describing population structures of *Callitris columellaris* at a continental scale was published in *Forest Ecology and Management*. *Callitris columellaris* was shown to be a useful bio-indicator of change resulting from the effects of climate, bushfire and land management.
- Information gained from this project has been used in development of a draft fire management plan 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 12–18 months)

Publish a paper on the influence of climatic factors on fire occurrence in semi-arid ecosystems.

Fire regimes and biodiversity decline in the Kimberley

SPP# 2007-008

Team members

I Radford (1.0), R Fairman (1.0).

Context

Recent studies in the Northern Territory have shown declines in critical weight range (CWR) mammals (35g-5kg) and some species of birds and shrubs. Biodiversity declines in otherwise intact landscapes have been attributed to increased intensity and frequency of fires. Studies in central Australian arid environments have also highlighted the strong influence of fire, combined with introduced predators, on mammal species abundance. This evidence from both the tropical savannas and arid environments has obvious implications for northern regions in Western Australia including the Kimberley, as these regions have also apparently undergone major shifts in fire regimes. A direct link between abundance of threatened animals and fire regimes in this region has yet to be established. This study will establish whether fire has a strong influence on abundance of threatened taxa in the north Kimberley (Mitchell River region), the last mainland stronghold for many threatened CWR mammal species. Studies will also address the question of how fire influences CWR mammals by analysing vegetation structure and resource dynamics.

Aims

- Spatially quantify the fire history in the Mitchell River and Purnululu regions.
- Establish whether fire history influences 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) attributes, which might explain the effect of fire.

Summary of progress (2010/2011) and main findings

- Analysis of mammal surveys conducted at eight sandstone and eight laterite sites to test for effects of habitat, fire and vegetation structural changes on mammal populations showed there was no effect of fire or vegetation on mammal abundance, but a strong relationship with habitat type. Laterite woodlands had very few mammals relative to previous surveys while sandstone habitats had similar high abundance compared to previous studies in the region.
- Further studies have investigated mechanisms behind fire effects through repeated surveys at particular sites. Although fire strongly influenced vegetation structural dynamics there was only evidence for a fire impact on mammal abundance and associated fauna after one very large fire. This

suggests that mammal populations in sandstone habitats are relatively fire resilient when fires are small and of low intensity.

- Predatory mammals increased intake of larger prey items after fire. Northern quolls increased their intake of golden bandicoots and golden bandicoots increased their intake of skinks during the first year after fire (based on scat content analysis). This is probably related to removal of ground cover vegetation with fire and suggests that other predators (e.g. cats, dingoes, raptors) may also benefit from fire to the detriment of prey species.
- Grass-layer invertebrates experienced a strong but short-lived (<12 month) impact due to fire. Fire caused a decline in abundance of invertebrates of up to 80% immediately after the fire event. Full grass-layer invertebrate community recovery had occurred after a single wet season and no longer term community change was detected.
- Northern quolls showed no change in habitat use or home range size after fire in sandstone habitat.

Management implications

Persistence of CWR mammals will be favoured by fire mosaics with small burn patch size (<1 km^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 12–18 months)

Use results to inform development of a regional monitoring program in the north Kimberley to evaluate the effectiveness of fire and cattle management in maintaining mammal populations across all major habitat types.

Armillaria spread in karri

SPP# 1998-006

Team member

R Robinson (0.2).

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 (2010/2011) and main findings

- Guidelines for determining the occurrence of *Armillaria* root disease in karri regrowth stands were reviewed.
- Commenced re-assessment of plots in the Warren thinning experiment.

Management implications

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

Future directions (next 12–18 months)

- Complete assessment of Warren thinning experiment.
- Plan for second thinning of plots in the Warren thinning experiment.

The effect of wildfire on forest fungi

SPP# 1998-015

Team member

R Robinson (0.1).

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 effects of wildfire on fungi 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 (2010/2011) and main findings

- Presentation of results to Western Australian Naturalists' Club.
- Review paper on the impact of fire on fungal communities and species published in the *Australian Journal of Botany*.

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 12–18 months)

- Continue laboratory work to catalogue and identify voucher specimens collected.
- Continue analysis of the influence of rainfall and the resulting soil dryness index on macrofungal fruiting patterns.
- Re-assess plots in 2012 (15 years post-fire).

Forest health and vitality surveillance and monitoring

SPP# to be allocated

Team members

R Robinson (0.15), J Farr (0.2).

Context

Key Performance Indicator 17 of the *Forest Management Plan 2004-2013* (FMP) requires that DEC report on the severity status of weeds and pests and investigate the cause of any increase in severity

status as a result of management actions. DEC requires a structured approach to monitoring to identify significant weeds, diseases and pests and track their status over time.

Aim

Devise, establish and implement a forest health surveillance system for Western Australian forests.

Summary of progress (2010/2011) and main findings

- An outbreak of gum-leaf skeletonizer (*Uraba lugens,* GLS) was detected north of Manjimup in February 2010, with distinct centres of activity in Yanmah/Wheatley, Dingup/Kinkin and Quillben forest blocks. Canopy sampling for GLS at sites previously monitored for insect population activity during the 1980s was reactivated in Dec 2010. New plots were also established in areas to supplement the original plot locations. A total of 61 tree plots were assessed for GLS population levels with a mean population level of 824 larvae per kg. Aerial survey showed that over 250 000 ha of forest had been defoliated. A trial examining the effectiveness of pheromone lure traps developed in New Zealand was successful. Development of remote sensing techniques for GLS were initiated.
- Native (*Eucalyptus gomphocephala, E. rudis, E. occidentalis*) and exotic eucalypts in plantations and roadside and plantation contexts were inspected to survey psyllid populations. No evidence of *Cardiaspina jerramungae* outbreak was found on previous outbreak sites near Cranbrook. *Cardiaspina fiscella* was found damaging *E. botryoides* in Kings Park, Yarloop and Bridgetown. Suspected *Cardiaspina albitextura/densitexta* populations were examined in a roadside planting of *E. gomphocephala* near Mandurah, as yet there are no records of these species in Western Australia (precise species identification is yet to be confirmed). Extensive outbreak of *Creiis periculosa* was found on *E. rudis* in agricultural land between Boyup Brook and Williams.

Management implications

Pest and disease incursions can have major implications for economic and biological values of native forests and plantations and monitoring has a key role to play in timely and effective response to incursions.

Future directions (next 12–18 months)

- Prepare 2011-2012 pest, disease and quarantine status report for Western Australian forests.
- Provide input on Forest Health and Vitality requirements for the new FMP.
- Continue canopy sampling for GLS at the 61 sites established in 2010. Continue with developing remote sensing and GIS relationships for the GLS outbreak dynamic. The pheromone trapping protocol will be refined to investigate the relationship with moth captures, antecedent larval populations and defoliation intensity with the long term vision of developing cost effective long term predictive monitoring for this insect.
- The phenology of *U. lugens* will be investigated more fully to test the hypothesis that warm dry years can lead to two generations per year.

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

SPP# 2007-009

Team member

M Stukely (0.5).

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 treatments on dieback expression.
- Investigate the effect of retained over-storey 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 (2010/2011) and main findings

- Initial tree and mid-storey plant measurements were completed on the newly established permanent trial at five sites in Cobiac block in the Wungong Catchment. A sixth trial has been pegged. These six trials are on sites that represent different thinning regimes, dieback status and topographic positions.
- 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 has commenced.

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 12–18 months)

- Complete initial crown health assessments and tree measurements 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 conditions.
- Continue site selection and establishment of trials on different Havel forest site types, and under different thinning regimes, and carry out initial assessments and measurements on the new trials.
- Commence second measurements and assessments as appropriate on the earliest trials.

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 (0.1). 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. This study was established in December 2001 and has involved local volunteers in the establishment of a long-term invertebrate collection.

Aim

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 (2010/2011) and main findings

- Continued comparison of the Nuyts beetle collection of 263 morphospecies with beetle assemblages collected in the Bushfire CRC (384 morphospecies) and Walpole fine grain mosaic burning (445 morphospecies) projects. Results to date indicate a high level of local endemism in the beetle fauna of southern forests. Although less than 30km apart beetle assemblages collected for these three studies have only a small proportion of species in common.
- Autumn 2011; Patchy prescribed burning in the Nuyts Wilderness successful created a mosaic of burnt and unburnt patches within threatened Tingle forest to ensure unburnt refuges survive future wildfires.

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.

Future directions (next 12–18 months)

- Finalise comparison of Nuyts, Walpole Fire Mosaic and Bushfire CRC study beetle assemblages and commence a baseline biogeographic meta-analysis.
- Establish monitoring of a number of declared threatened invertebrates species within threatened Tingle forest communities across a mosaic of vegetation types and fuel age.

Effects of timber harvesting on terrestrial vertebrates in medium rainfall jarrah forest

SPP# 1993-115

Team members

A Wayne (0.1), C Ward (0.2), C Vellios (0.2), M Maxwell (0.2).

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.

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 (2010/2011) and main findings

- Spotlight monitoring on three standardised transects was maintained at six repeat surveys per transect per year. Western ringtail possum populations remain at very low levels, only one individual has been detected on transects since 2001. Previously there was an average of around 10-12 individuals (up to 33) per transect per night prior to the decline.
- Data collation and validation for previous trapping and spotlighting is complete and up-to-date. Analysis and preparation for publication are underway.
- Knowledge gained from the project has been used in developing a framework to guide future research on forest fauna issues.

- Management practices to promote fauna conservation in forests managed for timber production were presented to an international workshop on tree retention held in Stockholm, Sweden.

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 12–18 months)

- Publish findings of immediate and short-term responses of medium-sized mammals to jarrah forest timber harvesting, based on trapping data.
- Analyse and publish the findings of the abundance of possums over time based on spotlight monitoring data.
- Information on the effects of silvicultural practices on biodiversity will be summarised for presentation to the expert panel convened for the review of silviculture.

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 jarrah forest on them

SPP# 1993-095

Team members

K Whitford (0.3), D Feeniks (0.1).

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 ecological 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 process 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 (2010/2011) and main findings

- CWD has now been resurveyed on all 48 FORESTCHECK sites using six 200m-long sampling transects.
- Analysis of data from these surveys has identified important factors affecting the volume, diameter distribution, condition and decay of CWD.
- We have also resurveyed FORESTCHECK plots after they have been burnt to determine the impact of fire on CWD volume and decay.

Management implications

This research contributes to knowledge of hollows and hollow use in the jarrah forest and the results provided the basis for much of Appendix 5 of Sustainable Forest Management Guideline No.1, 2004, *Silvicultural Practice in the Jarrah Forest*. Recent results from this study have been used in the *Jarrah Forest Silviculture Reference Manual*.

Future directions (next 12–18 months)

- Further analysis of CWD data will be completed and will include identification of gaps in knowledge required to fulfil the aims of this study. The potential for using this data to model the accumulation and decay of CWD will be investigated.
- An analysis of the complete set of log hollows data will also be completed and the direction of this part of the study will be reviewed.

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

SPP# 1999-021

Team member

K Whitford (0.2).

Context

Timber harvesting and forest management activities impact on soil physical and chemical properties. This study evaluated indicators of soil physical and chemical status, and contributed 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 (2010/2011) and main findings

- Further analysis of data from this study has identified significant interaction between pre-harvest soil bulk density and soil gravel content in determining soil compaction. A manuscript was prepared and has been submitted for publication.
- Findings from this study have been 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 Interim Manual of Procedures for the Management of Soils Associated with Timber Harvesting in Native Forests and the draft Soil and Water Conservation Guideline.

Future directions (next 12–18 months)

- Finalise publication of a manuscript on the adaptive trials of cording.
- Revise and submit for publication a manuscript on the effects of fire on soil carbon.

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 member

K Whitford (0.2).

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 (2010/2011) and main findings

- A Science Division information sheet based on seed forecasting in jarrah forest was published.
- A manuscript on jarrah seed fall has been prepared and submitted for publication.

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 12–18 months)

- Finalise publication of manuscript on jarrah seed fall.
- Assess, fell and strip additional trees to add to the data set used in developing a tree based seed crop assessment procedure.
- Prepare manuscript on the development of the tree based seed crop assessment procedure and promote the application of this assessment procedure in shelterwood silviculture.

Control of jarrah leafminer: selective retention of JLM resistant trees and ground coppice in a demonstration forest plot

SPP# 1993-097

Team member

A Wills (0.01).

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.

Aim

Provide a visual demonstration of improvement in stand health and productivity by management practices for control of jarrah leafminer.

Summary of progress (2010/2011) 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 12–18 months)

Inspect site annually and carry out coppice removal on treated areas as required.

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

SPP# 2001-005

Team members

A Wills (0.3), J Farr (0.01).

Context

Understanding the factors controlling the distribution of invertebrates in the jarrah forest landscape is important for ecological 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 (2010/2011) and main findings

- Findings from the project were synthesised and summarised in a PowerPoint presentation. Key findings are that incised valleys of the Darling Range provide niche diversity through microclimatic and habitat diversity for invertebrate species. High beta diversity over short distances provides for high gamma diversity of invertebrates within and across valley systems.
- Low frequency of occurrence of most species makes it difficult to draw conclusions about 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.

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. 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 12–18 months)

- Update database and analyse the combined dataset.
- Write up and publish results in a refereed journal.

Monitoring the northern extent of jarrah leafminer outbreak

SPP# 2009-011

Team members

A Wills (0.04), J Farr (0.01).

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 (2010/2011) and main findings

Report of 2009 survey in preparation as review of possible factors limiting northwards expansion of outbreak.

Management implications

Biomass productivity of jarrah and forest ecosystem health in the northern jarrah forest is presently unaffected by JLM.

Future directions (next 12–18 months)

- Draft five year report on extent of JLM in northern Jarrah forest.
- October 2011 census of JLM infestation at 48 FORESTCHECK sites.

Bushfire Cooperative Research Centre (CRC) Project B1.1: Managing fires in forested landscapes in south-west Western Australia

SPP# 2007-003

Team members

R Wittkuhn (1.0), L McCaw (0.2), R Robinson (0.2), J Farr (0.2), B Ward (0.1), G Liddelow (0.2), V Tunsell (0.09), P Van Heurck (0.1), A Wills (0.2).

Context

Understanding long-term effects of fire on the floristics and structure of forested landscapes is important for developing and implementing ecologically appropriate fire regimes and for managing fire for the protection of life and property. This study incorporates the known fire history in the Frankland District (in the form of maps that date back to 1953) to establish survey plots that investigate the impact of fire history on diversity and abundance of flora, fauna, invertebrates and fungi.

Aim

Improve understanding of the ecological effects of fire at landscape scale by comparing the flora and fauna in forest areas that have experienced different fire regimes over the past five decades.

Summary of progress (2010/2011) and main findings

- A manuscript describing the GIS mapping of fire interval and fire season sequences was published in the on-line journal *Fire Ecology*.
- A paper describing the influence of variation in fire interval sequences on plants, vertebrates, fungi and invertebrates was published in *Forest Ecology and Management*. The main finding of this paper is that the pattern of fire interval sequence has little influence on the species composition of any of the taxonomic groups.
- A Fire Management Guideline to inform fire planners and practitioners of the implications of this research was prepared and posted to the Fire Management Services website.
- Collaboration with a PhD student from France resulted in a scientific paper published in *Landscape Ecology* comparing the characteristics of fire regimes in Mediterranean environments in south-west Western Australia and south-east France.

Management implications

- Provision of scientifically-based guidelines for the appropriate fire frequency in the southern jarrah forest will achieve a range of land management objectives.
- Development of protocols for the collection, digital capture and attribution of fire information at the landscape and plot scale will improve management of fire history data.

Future directions (next 12–18 months)

This project has been completed.

Fire, fragmentation, weeds and the conservation of plant diversity in Wheatbelt Nature Reserves

SPP# 2009-005

Team members

C Yates (0.1), C Gosper (0.1). External Collaborators: 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 116ha) 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 experienced by 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 (2010/2011) and main findings

- A paper based on a comparative analysis of historical fire regimes in the fragmented landscape of the wheatbelt and continuously vegetated areas in the Great Western Woodlands was published in the *International Journal of Wildland Fire*.
- In studies of vegetation community composition and structure across a time-since-fire gradient, it was found that tallerack mallee-heath shows a decline in species richness and senescence in structure when long-unburnt (>50 years post-fire), whilst mallee does not. One manuscript arising from this work is in press at *Austral Ecology* with another in preparation.
- Measurement of vital attributes (mortality and fecundity) for select 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 in preparation and an information sheet was produced.
- The measurement of the impacts of chaining and burning on mallee-heath was completed. A second paper arising from this work was published in *Rangeland Ecology and Management* and the findings, that chaining and burning reduces recruitment in serotinous obligate seeders and the resprouting capacity of mallees, were incorporated into a revised Fire Management Guideline on the practice.
- A manuscript reporting on an experiment investigating whether fire and other disturbances interact to reduce resistance of eastern wheatbelt plant communities to weed invasion was published in *Biological Invasions*. Weed invasion was greater at nutrient enriched edges of reserves, irrespective of whether these were burnt or not. Invasion in reserve interiors was minimal.
- A presentation summarising the findings of the project and management implications was given at a DEC fire management workshop at Narrogin.
- An article summarising the main findings of the project was published in *LANDSCOPE*.

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 12–18 months)

Complete publication of scientific manuscripts arising from this work.

Fire regimes and impacts in transitional woodlands and shrublands

SCP# 2010- 011 (SPP# to be allocated)

Team members

C Yates (0.1), C Gosper (0.9). External Collaborators: S Prober, G Wiehl CSIRO.

Context

The Great Western Woodlands (GWW) is an internationally significant area with great biological and cultural richness. This 16Mha 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 (250–350 mm), 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.

Aim

Investigate the effects of time since fire and fire interval on assembly and recovery of plant community composition, development of ecosystem structure, and fuel dynamics.

Summary of progress (2010/2011) and main findings

- A paper based on a comparative analysis of historical fire regimes in the fragmented landscape of the wheatbelt and continuously vegetated GWW was published in the *International Journal of Wildland Fire*.
- 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.*
- Soil nutrient content, plant species richness, community composition and vegetation structure has been sampled at 52 sites in gimlet woodland across a time since fire gradient, ranging from two years post-fire to long unburnt. Sample identification and data manipulations are ongoing.
- Preliminary investigations on methods of determining the age of long-unburnt sites through dendro-chronology and relationships between plant size and age have commenced.

Management implications

The research will inform ecological fire management that will benefit the outstanding natural values of the GWW.

Future directions (next 12–18 months)

- Develop a robust methodology for estimating the age of sites burnt prior to the availability of remotely sensed imagery.
- Complete sample identification, data entry and analyses to describe how gimlet woodlands change in composition, diversity and structure with increasing time since fire
- Complete publication of scientific manuscripts and information sheets arising from this work, and communicate main findings to relevant stakeholders.

MARINE SCIENCE

PROGRAM LEADER: CHRIS SIMPSON

The broad goal of the of the Department of Environment and Conservation's (DEC's) Marine Science Program (MSP) is to ensure DEC's marine biodiversity conservation and management programs are based on good science. Specifically, the MSP 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 (MPA), threatened marine fauna and marine biodiversity generally. The MSP also coordinates and manages external marine research programs such as the current investigation into the ecology of the Ningaloo Marine Park (NMP) that is undertaken as part of the Western Australian Marine Science Institution (WAMSI).

The research and monitoring programs undertaken by the MSP are based around the research and monitoring strategies identified in MPA management plans and threatened species recovery/management plans ensuring that all activities are clearly linked to departmental priorities and programs.

WAMSI Node 3: Science administration, coordination and integration

Core project.

Team members

K Waples (0.6), C Simpson (0.1).

Context

In 2005 the state government allocated $5million to undertake research at Ningaloo Marine Park that would underpin its management. A research plan was developed in consultation with DEC marine resource managers and scientists 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. Research within WAMSI was divided into several themes, each with a lead agency. DEC is the leader of Node 3 of WAMSI which addresses research in marine biodiversity and conservation. Key ecological and biodiversity elements of the Ningaloo research plan were accepted as the science plan for Node 3 of WAMSI.

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 which include up to 20 subprojects. Each project area is led by a different institution/university. Thus the coordination and administration role entails ensuring that all project plans are in place and are running smoothly 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.

Integration of research within the NRP is managed through the formation of the Ningaloo research coordinating committee (NRCC) and through the following activities which serve to provide forums for sharing information, increasing collaboration between scientist groups and engaging managers and stakeholders:

- Annual Ningaloo Research Symposium
- WAMSI Operations Group

- WAMSI cross-nodal symposia and meetings
- Directed workshops for specific projects.

Aims

- Ensure the coordination and administration of the research program conducted under Node 3 of WAMSI.
- Ensure the integration of this research program with other research within WAMSI and with external programs relevant to the NMP.
- 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 research undertaken through Node 3 of WAMSI.

Summary of progress (2010/2011) and main findings

- Discussions were held with Exmouth District staff to discuss WAMSI research findings and how best to achieve knowledge uptake within the district.
- Public presentations on WAMSI and DEC Ningaloo research were made in Exmouth in July 2010 and May 2011. A CSIRO scientist was hosted within the Marine Science Program for 2 months to advance the MSE model activities and ensure they incorporate DEC management questions and needs for NMP.
- Milestone and final reports have been submitted and approved by WAMSI for a number of the research projects and a draft final report for Node 3 research is in preparation.
- Joint communication activities have been coordinated with the Ningaloo Collaboration Cluster and AIMS.
- The database on research at Ningaloo between 2005 and 2011 has been updated and complemented by a list of science references published on Ningaloo during that time period.
- Meetings have been held with DEC staff from relevant regional offices and branches that will have a use for the information produced through this research program to discuss their specific information needs and preferred delivery formats.
- Meetings have been held with WAMSI project leaders to discuss research findings, outputs and their full implications for management.
- 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 II.

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 NMP 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 and programs conducted by DEC.

Future directions (next 12–18 months)

- Complete the Node 3 Final Report and summary of Ningaloo research.
- Coordinate presentation of key findings and an overview of the Ningaloo research at the WAMSI Conference in September 2011.
- Further develop the knowledge transfer and uptake framework and submit a paper for publication in a peer reviewed journal on the framework and process.
- Ensure the findings and information from the Ningaloo research are disseminated to all relevant DEC users.

Conservation of marine turtles in Western Australia

SPP# 1993-040

Team member

B Prince (0.75).

Context

All marine turtles found in Western Australian waters are listed as threatened species by the state and federal governments. 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 over the past decade 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, as outlined in the recently completed Western Australian turtle recovery plan.

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 within species at the regional level 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 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 (2010/2011) and main findings

- A paper on olive ridley turtles in Western Australia was accepted by *Marine Turtle Newsletter*.
- A paper on Catch-Mark-Recapture data for Varanus Island nesting hawksbill turtles was submitted to *Marine Biology*.
- A data report was prepared on historical time-series data from Exmouth Gulf.

Management implications

The provision of knowledge will allow appropriate conservation and management programs of marine turtle stocks in Western Australia to be developed to minimise the impacts of human activities on these animals.

Future directions (next 12–18 months)

The project is to be reviewed in 2011/2012 as part of a broader review of turtle research and monitoring in DEC.

Development of a strategic marine research plan for the Western Australian Department of Environment and Conservation: 2010-2015

Core Project

Team members

S Wilson (0.1), A Kendrick (0.1), C Simpson (0.1).

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 WAMSI. 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.

Aim

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 (2010/2011) and main findings

- A report on the strategic marine research priorities for DEC was completed and distributed to CSIRO, AIMS and the UWA Oceans Institute as input to their research planning for the next three to four years.
- A detailed list of specific research projects is being prepared as an appendix to the strategic plan. This will be a dynamic list, periodically updated to reflect changing research outputs.
- A paper on research and monitoring priorities in marine protected areas has been drafted and will be published in 2011-2012. The study collates research priorities identified by managers and scientists around Australia and examines their perceptions of research requirements. This is a collaborative project between DEC, Australian National University (ANU) and the federal Department of the Sustainability, Environment, Population and Community (DSEWPaC).
- A state Government Marine Research Priorities report was completed and provided to the WAMSI Strategic Programs Committee as an input to the development of WAMSI II.
- Annual research planning meetings were held with regional marine park staff and feedback from these meetings contributed to the development of the strategic plan.

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 12–18 months)

Progressive implementation of the strategic marine research plan.

Strategic plan for the development and implementation of the Western Australian Marine Monitoring Program (WAMMP)

SPP# to be allocated

Team members

K Friedman (0.1), C Simpson (0.05).

Context

The successful establishment of a long-term, broadscale, institutional marine monitoring, evaluation and reporting (MER) program requires a strategic approach. The strategic plan for the WAMMP will outline the context, rationale, major tasks, timelines and delivery models that are required in the development and implementation of an integrated long-term, state-wide marine protected area and threatened marine fauna monitoring program in Western Australia's coastal waters.

Aim

Develop a strategic plan to guide the development and implementation of an integrated long-term, state-wide marine protected area and threatened marine fauna MER program in Western Australia.

Summary of progress (2010/2011) and main findings

- The draft strategic plan to guide WAMMP has been further developed and is currently being finalised.
- A standard WAMMP field operations plan has been developed and implemented.
- An operational framework to support the annual Marine Parks and Reserves Authority review process has been developed and implemented.

Management implications

The development and implementation of the strategic plan for marine MER within DEC's marine conservation programs in an adaptive management context will guide the development and deployment of DEC's marine monitoring capacity over the next ten years. Ultimately the WAMMP will provide the data to continuously improve the efficiency and effectiveness of DEC's marine operational management programs.

Future directions (next 12–18 months)

Publish the strategic plan by December 2011.

WAMMP sub-project 1: asset knowledge review and standard operating protocol documentation

SPP# to be allocated

Team members

K Friedman (0.2), C Simpson (0.1), A Kendrick (0.1), S Wilson (0.1), K Bancroft (0.1), K Onton (0.1), T Holmes (0.1), M Rule (0.1), K Waples (0.05).

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 active adaptive management for the conservation of marine biodiversity.

The primary purpose of monitoring programs is to identify undesirable changes in asset condition as a result of human pressures (as expressed relative to a management target) and to instigate management response/s to mitigate these effects. Monitoring programs must, therefore, be designed to detect changes when they occur, and identify whether these changes are caused primarily by natural factors, human use or climate change, so that appropriate management responses can be formulated and implemented. Use of a condition-pressure-response monitoring framework, assists managers in assessing management efficiency and effectiveness, which is a critical element of an adaptive management framework.

Aim

Develop asset knowledge reviews that identify what to measure, how to measure these indicators with due consideration of scientific 'power', cost, relevant historical data and practicality; and why these indicator/s and methods were chosen.

Summary of progress (2010/2011) and main findings

- Asset knowledge reviews for coral, seagrass and mangrove, pinnipeds, little penguins and water quality were produced.

- The asset knowledge reviews for coral and fish communities were reformatted for publication in the scientific literature.
- A draft report outlining the design for a Marine Information Management System has been completed. The report defines hardware, software and staffing requirements that are needed to support information management and operational needs.

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.

Future directions (next 12–18 months)

- Continue to document and publish WAMMP strategic documents such as the strategic plan, asset knowledge reviews and WAMMP guidelines.
- Initiate four new reviews from the following asset list: dugong, stromatolites, sharks and rays (including manta rays and whale sharks) and turtles.
- Develop guidelines on the development of standard operating procedures (SOPs) within WAMMP.
- Refine interim SOPs as field procedures are trialled and protocols are standardised.

WAMMP sub-project 2: historical time-series development

SPP# to be allocated

Team members

K Friedman (0.1), K Bancroft (0.3), C Simpson (0.05).

Context

Extensive monitoring of the marine environment of Western Australia has been undertaken over the last three decades or more by state and federal government agencies, universities, industry and community groups. 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 the Western Australian Marine Monitoring Program (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. This will further help to ensure relevant past and future datasets are comparable and will also assist in designing the temporal and spatial scales of WAMMP monitoring programs. Historical timelines are, potentially, also a key aid in improving our understanding of climate change impacts on marine biodiversity over the past several decades.

Aims

- Develop a framework outlining the decision rules to guide the construction of historical time-series on asset condition, pressure and management response and on accessing data for high priority biodiversity assets identified in marine protected area (MPA) management plans and threatened species recovery plans.
- Incorporate datasets into MPA annual report cards that are part of the Marine Parks and Reserves Authority (MPRA) audit process (see WAMMP sub-project 4).

Summary of progress (2010/2011) and main findings

- The Historical Time-series Development guideline was completed. A historical time-series for coral community data from Ningaloo Marine Park (NMP) was used to trial the guidelines.
- Preliminary assessment of historical condition data for most assets listed as key performance indicators in MPA management plans, with special focus on water quality (Marmion Marine Park),

coral (NMP and Montebello/Barrow Islands marine conservation reserves), seagrass (Marmion and Jurien marine parks) and pinniped communities (NZ fur seal state-wide), was completed and included in the 2010 MPRA annual review of MPA management.

Management implications

The construction of historical data will capture past DEC investment in marine monitoring programs and assist the design of future 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, thereby improving the efficiency and effectiveness of DEC marine conservation and management programs.

Future directions (next 12–18 months)

- Submit a manuscript on the Historical Time-series Development guidelines with worked examples for external publication by December 2011.
- Continue to collate historical information on previous marine monitoring/research programs to assist in the temporal and spatial design of future WAMMP monitoring programs.
- Continue the identification, retrieval and assessment of historical time-series (including data from sources external to DEC) of asset Condition-Pressure-Response (CPR) data with marine park coordinators and other DEC staff for progressive inclusion into the MPRA audit process (see WAMMP sub-project 4) and for the development of standardised time-series.

WAMMP sub-project 3: 'fit to park'

SPP# to be allocated

Team members

K Friedman (0.3), A Kendrick (0.1), S Wilson (0.1), K Bancroft (0.4), T Holmes, (0.4), M Rule (0.4).

Context

The WAMMP sub-project 3: 'fit to park' 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 temporal and spatial scales of WAMMP monitoring programs prior to their implementation. This will ensure that monitoring locations and monitoring timing and frequency allow biodiversity asset monitoring data to be comparable within and between major geographical areas of interest (e.g. marine protected areas (MPAs)).

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 MPA management plans.
- Progressively implement asset CPR monitoring programs for threatened marine fauna according to established DEC priorities.

Summary of progress (2010/2011) and main findings

- Coral communities were surveyed in Ningaloo Marine Park and the Montebello/Barrow Islands marine conservation reserves. Standard and rapid community monitoring survey techniques were used to get quantitative and semi-quantitative records of coral bleaching at Rowley Shoals, Ningaloo, Shark Bay and Jurien Marine Parks.
- Seagrass monitoring sites were surveyed at Shark Bay, Jurien and Marmion marine parks under both historical and new sampling regimes. Macroalgae monitoring was commenced at Marmion Marine Park.

- Mangrove monitoring was completed at the Montebello Islands, and significant progress was made in capturing and processing remote imagery of mangrove areas in all parks that support this asset.
- Invertebrate monitoring of settlement of rock lobster was completed in Ningaloo Marine Park (NMP).
- Finfish monitoring was completed at Jurien Bay, Shark Bay, Ningaloo, Montebello/Barrow Islands and Rowley Shoals marine protected areas.
- Turtle monitoring was undertaken in the Shark Bay, Ningaloo and the proposed Dampier Archipelago marine parks.
- A decadal survey of New Zealand fur seal populations was undertaken along Western Australia's south and south-west coastlines.
- Coastal sea-bird and shore-bird populations were monitored in the Swan Estuary, Shoalwater Islands and Rowley Shoals marine parks. A little penguin population survey was completed in the Shoalwater Islands Marine Park which suggests the significant decline in numbers observed between 2008 and 2009 is continuing.
- Water and sediment quality monitoring was undertaken at slipways in NMP. Water temperature monitoring arrays were established and maintained in all marine parks.

Management implications

The CPR data being collected on the assets (outlined above) will be available for marine park coordinators and regional staff to help them assess the efficiency and effectiveness of management actions. The data will also be incorporated into the Marine Parks and Reserves Authority (MPRA) audit process of Western MPA system.

Future directions (next 12–18 months)

- Finalise the guidelines for determining the spatial and temporal scales of asset CPR monitoring programs with a manuscript to be submitted for external publication.
- Progressively implement CPR monitoring programs using asset priorities outlined in MPA management plans.
- Progressively implement CPR monitoring programs for threatened marine fauna according to established DEC priorities.
- Continue focus on integration of monitoring across assets, improving the efficiency of field data collection and data post-processing.

WAMMP sub-project 4: MPRA/DEC audit support and management effectiveness reporting

SPP# to be allocated

Team members

K Friedman (0.1), C Simpson (0.05).

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:

- an annual review (including an asset condition-pressure-response (CPR) report card) of the progressive implementation of the strategies in the MPA management plans,
- audit of management performance for each MPA on a periodic basis, partly based on the preceding three to five annual reviews, and
- a ten-year audit of the implementation of the management plan.

A comprehensive MPA performance assessment report, including a CPR report card, is presented to the MPRA annually. The WAMMP assists DEC regional MPA staff in this regard, by providing asset CPR monitoring data and advise for use in 'populating' the MPRA's MPA performance assessment framework.

Aim

Assist DEC MPA managers 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 (2010/2011) and main findings

A process for the annual delivery of science information to MPA managers has been developed and documented. This process involves the updating of a monitoring reporting framework and annual marine park reports, listing all of the current asset monitoring information that is used to drive management effectiveness.

Management implications

The MPRA audit process provides an annual understanding of asset CPR for all Western Australian MPAs and is a statutory requirement of DEC under the *Conservation and Land Management Act 1984*. The same 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 12–18 months)

- Finalise of the process (including roles, responsibilities and capacity between the Marine Science Program and regional MPA managers) to meet MPRA audit reporting requirements.
- Roll-out of a process (and related reporting) for the provision of asset CPR monitoring updates.

WAMMP sub-project 5: community participation and liaison

SPP# to be allocated

Team members

K Friedman (0.08), K Waples (0.05).

Context

Community engagement and participation is recognised as a key strategy to develop better links between managers, scientists and the community at large. Community partnerships within the context of the WAMMP offer the opportunity of extending the scope of an early warning system for detecting change in the marine environment and opportunities to inform and improve understanding of marine conservation issues and priorities in the general population.

Aims

- Successfully engage with 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 the community is involved in managing the health of our marine and coastal environment.
- Ensure the data collected by the community will complement the monitoring data collected by Government agencies and scientists so that, together these data will be used by management agencies and local communities to help manage human impacts on their local marine environment.

Summary of progress (2010/2011) and main findings

- Six presentations to community groups and three internal presentations to DEC groups.
- A community coral monitoring program was continued in Ningaloo Marine Park with greater focus on commercial tour operators.

- Volunteers were supported and trained in the collection, post-processing and reporting of seagrass condition-pressure-response monitoring information in the metropolitan, Jurien and Shark Bay marine parks. DEC coral and fish monitoring surveys at the Montebello/Barrow Islands marine conservation reserves included community participation.

Management implications

The management of MPAs and threatened marine fauna will benefit from increased community understanding resulting from extensive communication of, and direct community participation in, WAMMP.

Future directions (next 12–18 months)

- Continue community presentations on the objectives of WAMMP.
- Continue to foster public participation in WAMMP programs where possible.

WAMMP sub-project 6: marine information management system

SPP# to be allocated

Team member

K Friedman (0.05), F Mayer (0.5).

Context

The research and monitoring capacity within the Marine Science Program (MSP) 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 MSP, particular emphasis on the long-term datasets required for the Western Australian Marine Monitoring Program (WAMMP).

Aim

Establish and implement a best practice information management system for the MSP, with particular emphasis on the management and presentation of long-term datasets produced by WAMMP.

Summary of progress (2010/2011) and main findings

- A review of the marine information management requirements of MSP (and WAMMP), including implementation costs over three years, has been completed.
- Interim guidelines for MSP data collection and information management have been developed.
- A data warehouse architecture has been developed and trialled as a prototype.
- A literature management system is currently being implemented across MSP.
- 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 12–18 months)

Continue development and implementation of a marine information management system for MSP and WAMMP.

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

SPP# 2009-013

Team members

A Kendrick (0.2), M Rule (0.2).

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 by Hodgkin and Clark (1999) from surveys conducted in 1984 and 1987. The fauna was found to be relatively diverse compared to 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 (2010/2011) and main findings

- Seasonal invertebrate sampling was completed with Frankland District staff in July 2010, October 2010, February 2011 and April 2011.
- Samples from all field trips were processed in the laboratory and a voucher specimen collection is being used to identify unknown species.
- Preliminary analyses indicate that the benthic invertebrate community differs markedly in the major habitats of the inlet system. The peripheral sand flats of the Nornalup Inlet, for example, support several relatively large bivalve species that do not occur in the deeper basin habitats. The overall abundance of invertebrates is also typically highest on the peripheral sand habitats.
- A survey of benthic algae markedly increased the number of algal species recorded from the WNIMP and has been published in the *Journal of the Royal Society of Western Australia*.

Management implications

This study will provide knowledge of how and why benthic invertebrate communities in the WNIMP are structured in space and time. Such 'inventory' and/or 'baseline' information is required to determine the composition of these ecological assets in relation to natural processes, and to benchmark their condition with regard to the impact of current and future anthropogenic impacts.

Future directions (next 12–18 months)

- Seasonal invertebrate sampling will continue for one more year.
- Several papers will be submitted for publication.

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 (0.2), M Rule (0.15).

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 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 Island).
- 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 (2010/2011) and main findings

- Sixteen mainland and offshore intertidal reef sites were sampled in the MMP and SIMP by Marine Science Program and Swan Coastal District staff. This completed the 'spatial' component of the sampling.
- A collection of voucher specimens is being progressively developed, and will be maintained, as a taxonomic aid. This collection is being used to identify unknown species.
- Data is being collated and entered into a database for analysis. Preliminary analyses suggest that high levels of variation exist between the community compositions of different platform reefs.

Management implications

- This study will provide a basis for the design and implementation of comparative intertidal research in marine parks and reserves across Western Australia.
- Inventory and baseline information will be used to determine the composition of ecological values in relation to natural processes, and to benchmark their condition with regard to the impact of current and future anthropogenic impacts.

Future directions (next 12–18 months)

- Sampling will occur at a sub-set of sites during the 'summer' season in 2011-2012.
- Sites at Garden Island and Carnac Island will also be sampled, if conditions permit.
- Analysis and publication of results.

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

SPP**#** 2009-003

Team members

S Wilson (0.3), T Holmes (0.3), K Onton (0.1).

Context

Climate change and over-fishing are widely regarded as the major threats facing coral reef communities worldwide. Typically fishing has a 'top-down' affect on communities, through the removal of large predators, whilst climate change causes degradation of habitat which effects fish that recruit, feed and shelter within corals. The independent impact 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 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 impacts to biodiversity of fish communities and fish populations.

Aims

- Determine how habitat degradation instigated by climate change and changes in predation instigated by fishing pressures effect 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 (2010/2011) and main findings

- Information was collected on fish communities on patch reefs of differing habitat composition inside and outside of sanctuary zones.
- Data on abundance and distribution of juvenile fish and coral bleaching along Ningaloo Reef was collected.
- A manuscript identifying habitat associations of juvenile fish was published in *PLoS ONE*. The study demonstrates corals of high structural complexity are important habitat for ~half the species investigated. The study also shows algal meadows are important juvenile habitat for some species, including species targeted by fishers. An oral presentation of this paper was delivered to the Australian Coral Reef Society at Coffs Harbour, New South Wales in September 2010.
- A manuscript assessing extinction vulnerability of fish was published in *Ecology Letters*. This paper assesses 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.
- Predation data collected in 2009-2010 in collaboration with CSIRO is currently being analysed and prepared for publication. Preliminary findings were presented to the public in Exmouth July 2010.
- An article on the relationship between fish and corals was published in *LANDSCOPE.*
- Fish for the dietary study have been collected from the field and processing of samples is underway.
- 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.

Management implications

- Knowledge on the combined effects of fishing on fish recruitment will ensure effective management of recreational fishing that may alleviate pressures placed on coral reef biodiversity.
- The project will identify appropriate indicators for ongoing monitoring programs, particularly those undertaken by Marine Science Program and identify finfish species that require protection from recreational or commercial fishing.

Future directions (next 12–18 months)

- Prepare a manuscript for submission to international journal based on 2009-2010 data.
- Complete dietary assessment of fish species that may be affected by fishing.
- Analyse data collected during 2010-2011, determine if more replication required before data prepared for publication.
- Assess the impact of 2011 coral bleaching on fish recruitment.
- Analyse satellite imagery and algal samples collected from Ningaloo lagoon. Prepare manuscript for publication which examines temporal variation in the composition, biomass and size of algal meadows.

Preliminary assessment of diseases affecting Western Australian corals

SPP# 2009-011

Team members

K Onton (0.3), S Wilson (0.02).

Context

Coral diseases have contributed significantly to coral reef degradation in locations around the world over the last three decades. However there is little information on the prevalence and type of disease on Western Australian coral reefs. Ningaloo Reef is the largest fringing coral reef in Australia, home to highly diverse marine life and is regarded as an icon of Western Australian marine conservation. Research into coral disease at Ningaloo Marine Park (NMP) will create a baseline data set that can be used to measure how climate and anthropogenic drivers threaten coral reef sustainability over time, and across regions with varying levels of anthropogenic influence.

Aims

- Review the current knowledge of coral diseases on Western Australian reefs.
- Document the prevalence of diseases affecting corals and the coral taxa/morphologies susceptible to various diseases within NMP.
- Characterise coral disease legions morphologically and histologically.
- Contribute to the development of coral disease standard monitoring protocols.

Summary of progress (2010/2011) and main findings

- A paper detailing the prevalence of coral disease at NMP has been accepted for publication in *Marine Ecology Progress Series*. This paper indicates occurrence of disease at NMP is similar to other locations in the Indo-Pacific. There is no indication that disease prevalence is related to human activities at Ningaloo, however disease was more prevalent at sites where coral feeding by the snail *Drupella* was high. The paper also provides an overview of disease occurrence in the region.
- Results from the study were presented as a poster at the Australian Coral Reef Society at Coffs Harbour, NSW in September 2010.
- Results of the study were presented at a public forum in Exmouth July 2010.

Management implications

The results of this study will provide an indication of the spatial and temporal distribution of various diseases providing information on the prevalence and identity of diseases affecting Western Australian

corals. This will assist in identifying the current threat posed by disease and provide a baseline for assessing any changes in impact. This will enable assessment of current management strategies designed to mitigate the impact of threats on coral communities.

Future directions (next 12–18 months)

- This study is now complete.

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

SPP# 2011-003

Team members.

M Rule (0.15), A Kendrick (0.2).

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. No significant areas of mangrove habitat, for example, currently exist within SBMP sanctuary zones. This project will provide the first comprehensive description of the variation among dense *Avicennia marina* stands in SBMP.

The outcomes of this one-year study will inform broader studies on mangrove ecology and mangrove-associated organisms in the SBMP. The project will also assist with the development of *in situ* monitoring methods and protocols which will be used to monitor mangroves in SBMP and more broadly across Western Australia.

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 (2010/2011) and main findings

Field work was completed in May 2011, when 12 mangrove sites were surveyed between Carnarvon and South Passage in SBMP. These data are now being collated and analysed.

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 12–18 months)

The data from the project will be analysed and published.

Western Australian regional-scale coral bleaching study

SPP# to be allocated
Team Members
J Moore (0.3), S Wilson (0.07), K Friedman (0.05), S Field (0.05), H Taylor (0.02), R Middlebrook (0.02), D Holley (0.01).

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 significant proportion 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. The extent and intensity of coral bleached, and the associated recovery and mortality of these communities, form the basis of this research project. The outcomes of this project will increase our understanding of threats to coral reefs in Western Australia and enhance management effectiveness to respond to similar events in future.

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 (2010/2011) and main findings

- Satellite sea surface temperature and *in situ* temperature anomaly data from loggers for June 2010 to present has been compiled for Western Australian waters.
- Preliminary examination of the data suggests that temperature profiles observed during the six months preceding May 2011 are likely to be some of the highest recorded for that period in Western Australian waters.
- Surveys of coral communities have been undertaken at marine protected areas at Rottnest Island, Abrolhos Islands, Shark Bay, Ningaloo and the Montebello/Barrow Islands.
- Preliminary analyses of the data suggest coral bleaching has had low to moderate impact in certain areas, with 20-60% of corals bleached. Some areas have been severely affected with up to 10% of coral bleached e.g. Bundegi in Exmouth Gulf and reefs around Coral Bay (Ningaloo Marine Park).
- Aerial surveys in the Montebello/Barrow Islands Marine conservation reserves and at Ningaloo Marine Park show extensive low level bleaching across both reserves, with moderate to high levels of bleaching observed in many areas.

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 12–18 months)

- Resurvey all sites within the next 3-6 months to collect recovery and mortality data.
- Present preliminary findings at national conferences and workshops.
- Publish findings in an international peer-reviewed journal.

- Develop management strategies for responding to future disturbance events on Western Australian coral reefs.

Comparison of underwater video 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 (0.09), M Rule (0.04), R Evans (0.04), S Wilson (0.03), K Friedman (0.02), G Shedrawi (0.02).

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 which 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 images capture 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 to 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 through 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 through 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 through 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 (2010/2011) and main findings

Field work was conducted in the Rowley Shoals Marine Park and video data collected during this trip were analysed.

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.
- The project will highlight the pro's and con's of each methodology, including cost and time analysis, to provide feedback to monitoring programs on which methodologies are most appropriate.

Future directions (next 12–18 months)

- Complete data collection and video analysis from Ningaloo and Jurien Bay Marine Parks.
- Analyse all data sets.
- Prepare a manuscript for submission to international journal within the next twelve months.

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

SPP# to be allocated

Team members

S Field (0.8), G Shedrawi (0.9), R Evans (0.9), K Friedman (0.05) J Huisman (0.05).

Context

The Gorgon Project (GP) that 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 GP includes a dredging program that will involve the removal and dumping of ~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 (MBIMPAs). The Gorgon MER project will also help inform future environmental impact assessments by improving predictions of the spatial scale and nature of the likely impacts of dredging and dumping activities on sensitive marine communities. Additionally, this project will increase the knowledge base of the MBIMPAs.

Aims

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

Summary of progress (2010/2011) and main findings

- Following the commencement of dredging, qualitative surveys of the coral communities at permanent sites were conducted in November 2010 and January 2011 with quantitative surveys completed in February and May 2011. The February survey quantified the extent of a bleaching event (increased water temperature) which affected coral communities throughout the MBIMPAs while the May survey allowed the quantification of the mortality of previously bleached coral communities.
- Monitoring of the pressure field associated with the dredging has been completed for the duration of the Gorgon MER through the maintenance of sediment taps, to quantify sediment deposition, and the monitoring of the extent and persistence of the dredge plume, through the interpretation of remotely sensed Moderate Resolution Imaging Spectroradiometer (MODIS) imagery.
- A number of other potential natural and anthropogenic pressures on the coral and fish communities are also being monitored to quantify any additional impacts to these communities.

Management implications

The program provides a baseline for assessing potential impacts and recovery of coral communities within the MBIMPAs, with a particular focus on potential impacts related to the dredging program for the GP. It also provides information that will assist DEC to protect and manage the MBIMPAs. 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 in Western Australia.

Future directions (next 12–18 months)

- Additional surveys of the coral and fish communities will be undertaken around the time of completion of the dredging program to provide an indication of the trend in the condition of these communities approximately 6 -12 months post-dredging.
- Monitoring of the pressure field will also be maintained for a similar duration to quantify the extent of impacts of residual dredge material at the dredge sites in addition to the re-suspension of material from the spoil ground.
- Results will be progressively published in international journals.

South coast pinniped survey

Core project

Team members

R Campbell (0.5), K Friedman (0.02), A Kendrick (0.1), K Bancroft (0.1).

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.

There are two resident species of pinniped in Western Australia, the NZFS, and the ASL. Both species 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 (2010/2011) and main findings

- A comprehensive survey of all known breeding sites of NZFS was conducted in January-February 2011 which found:
    - Abundance of NZFS had increased by a total of 17% over the past 12 years at an annual rate of approximately 1.2%.
    - Several colonies showed very large reductions in pup production from the levels in 1999, including a group of colonies between Esperance and Albany.
    - Pup mortality rate was uniform across the range (~1.4%) and was similar to that recorded in the 1999 survey.
- Three new NZFS breeding colonies were found at Chatham Island, Stanley Island and Bunker Bay (near Cape Naturaliste). One new breeding colony of ASL was found on Draper Island in the Recherche Archipelago. Some data on the breeding schedule of ASL were collected opportunistically.

- Training of DEC regional staff on the south coast in pinniped survey techniques was initiated to facilitate future smaller scale monitoring of pinnipeds as well as other threatened fauna species of the south coast of Western Australia (e.g. Cape Barren geese, Australian sea lions).
- A draft manuscript and a data report have been compiled and are undergoing internal review.

Management implications

The development and implementation of a long term monitoring program that is both cost-effective and logistically feasible will also allow us to tease apart natural and anthropogenic, including climate change, factors that influence abundance and distribution for 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 us to better understand current and future trends in interactions with commercial fishing operations and the general public, and to manage this interaction more effectively.

Future directions (next 12–18 months)

- Implement cost-effective annual surveys of selected sentinel colonies of NZFS to determine inter-annual variation in pup production due to stochastic and environmental effects.
- Continue the training and establishment of a state-wide monitoring program to determine the extent of pressure and response parameters of the two resident seal species in Western Australia.

SCIENCE APPLICATIONS

UNIT MANAGER: PAUL GIOIA

The Science Applications Unit focuses on managing the corporate biodiversity assets of the Division making available online databases of species occurrence, maps of where species have been recorded, and lists of species that have been recorded for any sized area within Western Australia.

Plant species richness and endemism within the South-west Australian Floristic Region

SPP# 2011-010

Team members

P Gioia (0.2). External Collaborator: S Hopper.

Context

The current DEC reserve acquisition and natural resource management process uses a range of inputs to help identify high priority areas with significant biodiversity values. Biodiversity indices such as species endemism and richness provide a valuable tool in this process. 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-west Australian Floristic Region 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 (2010/2011) and main findings

A literature review was conducted to assess methods for normalising sample effort (e.g. rarefaction) and using null models to inform the interpretation of richness nodes.

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 12–18 months)

- Recalculate species richness and endemism indices using 2003 data and compare with results using most recent data from the Herbarium.
- Finess the faunal richness maps for use within a regional planning context.

Provision of authoritative names of Western Australian taxa

Core function.

Team member

P Gioia (0.05).

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 minimised.

The Western Australian Herbarium is the recognised custodian of the names of Western Australian plants. 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, and the delivery of high quality information to a range of clients.

Aim

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.

Summary of progress (2010/2011) and main findings

- The WACensus application was upgraded to use new methods for identifying families and applying systematic order.
- A number of new groups have been added, including higher order names for all flora, slime moulds and fungi.
- Fauna names from the Western Australian Museum and Species and Communities Branch have now been incorporated into the same database. This will allow for a more integrated approach to managing names.

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.

Future directions (next 12–18 months)

- Further embedding of WACensus information into DEC's information systems.
- New names will be added as resources permit.

Online GIS biodiversity mapping (NatureMap)

Core function

Team member

P Gioia (0.45).

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 containing 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.

Aim

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 (2010/2011) and main findings

A major release of NatureMap was made available in August 2010 that included many enhancements requested at demonstrations and from user feedback. Examples include a new banded iron formation theme, many new reference layers, species occurrence data from Birds Australia, and enhanced functionality.

Management implications

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

Future directions (next 12–18 months)

- The underlying infrastructure NatureMap is based on will be reviewed and upgraded in line with industry standards.
- New reference layers and species datasets will be added.
- Specific bug fixes and urgent functionality requirements will be implemented.

Species database management software (Max)

Core function

Team member

P Gioia (0.05).

Context

There is a need to provide a standard mechanism for collection and management of plant species information. The mechanism should integrate with the Western Australian Herbarium's information systems. 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 Herbarium's specimen database.

Aim

Maintain updated species databases and provide facilities for entering specimen label information.

Summary of progress (2010/2011) and main findings

- Max was upgraded to support the inclusion of fauna names in WACensus. The periodic distribution of Max WACensus updates now include the new names.
- Max data tables have been upgraded to support higher level taxa.

Management implications

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 12–18 months)

- Complete the new fauna collecting book forms.
- Implement better support for site/species organised databases through customised forms.

Baselining the Wheatbelt Natural Resource Management (NRM) region (terrestrial)

SPP# 2011-009

Team members

B Bayliss (0.5), P Gioia (0.1), J Harvey (0.5). Consultant: A Rick.

Context

There is a need for baseline biodiversity data about the Wheatbelt NRM region, to fill knowledge gaps and to inform decision making by the Wheatbelt NRM (previously Avon NRM). This project will also provide data and information management support for related projects in the natural diversity program of the 2005 Avon Investment Plan. The project contains two sub-projects, wetlands and terrestrial. This sub-project describes the terrestrial component.

Aims

- Collate, analyse and disseminate Wheatbelt NRM biodiversity relevant data.
- Assist in developing a strategic conservation plan to direct the Wheatbelt NRM's natural diversity funding,
- Examine and report on gaps in knowledge and/or current natural diversity programs that restrict the Wheatbelt NRM from achieving its natural diversity goals.
- Develop benchmark descriptions of Wheatbelt vegetation, primarily the woodlands, and develop metrics to assess vegetation condition.

Summary of progress (2010/2011) and main findings

- An attribute database, the Avon Vegetation Map (AVM) database comprising 2 300 native vegetation source descriptions has been completed for the Avon Catchment Basin. These descriptions have been derived from a collection of ~70 source documents and standardised according to National Vegetation Information System criteria. Vegetation attributes have been linked to a GIS spatial layer digitised from the corresponding, largely hard copy vegetation maps covering the Avon Catchment Basin.
- The AVM dataset has been corporatised and will soon be included as a NatureMap reference and query layer: Changes have been made to the database structure to enable concatenation of multiple vegetation attributes as a prerequisite to labelling, visually rendering and querying outputs for each polygon in the spatial layer. These changes allow display and query through NatureMap including delivery of NVIS vegetation descriptions as HTML outputs for all polygons queried.
- A set of 170 linked web-based fact sheets have been prepared for installation onto the existing baselining theme in NatureMap. These include community and sub-community descriptions of wheatbelt eucalypt woodlands and, where possible, information about an accessible reference site for each sub-community. Benchmark descriptions based on available information about associated species, species richness, recruitment, old growth, litter and potential weed have been included in the descriptions for the twenty seven communities.
- Metrics for assessing vegetation condition have been field tested and are available for broader use.
- A report on the survey and analysis of plant communities growing on gypsum in the Western Australian wheatbelt has been internally reviewed and completed. It found floristic groups are strongly governed by the lake system they occur in and recommended further survey in certain lake chains and near unsurveyed areas near gypsum deposits and assessment of the communities where rare flora occurs.

Management implications

- The AVM database is being used in the development of vegetation (woodlands) description and condition assessment. The database provides an information resource for vegetation mappers, managers and Wheatbelt NRM stakeholders requiring information on the location and composition of native vegetation communities in the Avon catchment.
- The wheatbelt woodlands fact sheets will aid in assessing conservation values of remnant vegetation, monitoring effectiveness of management actions, landholder engagement, DEC staff induction and directing future research and restoration activities.
- Information used to prepare the fact sheets was used in a nomination, prepared by wheatbelt NRM, to the federal government that the wheatbelt eucalypt woodlands be classed as a Threatened Ecological Community under the *Environment Protection and Biodiversity Conservation Act 1999*.
- The vegetation description and condition indices will facilitate consistent collection of data for community classification and condition monitoring.

Future directions (next 12–18 months)

- Corporatising of the AVM dataset and inclusion as a NatureMap layer will be the final stage in the project.
- Incorporate the woodland fact sheets onto NatureMap together with supporting index, glossary and report.

PERTH OBSERVATORY

A/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.

Astronomical outreach and education

Core Function

Team members

R Martin (0.1), A Verveer (0.4), V Smith (0.1), A Williams (0.25), G Lowe (0.5), A Taylor (0.5).

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 (2010/2011) and main findings

- DEC is currently undertaking the development of a new strategic plan for Perth Observatory with input from relevant stakeholders. This process will be finalised in early 2011/2012.
- The Observatory supported charitable institutions by running an astronomical field night for the Organ Donation and Tissue Foundation.
- Volunteers are now running the star viewing sessions under the direct supervision of the volunteer coordinator.
- The number of visitors attending star viewing nights and day time guided tours totalled 3 828 for the year.
- Twenty-one 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.
-

Activity Measures

Activity	10/11	09/10	08/09	07/08	06/07	05/06
Star viewing sessions	72	77	102	93	143	183
Night visitors	3 461	3 604	4 334	4 371	4 234	5 420
Sunday guided tours	11	46	37	28	30	37
Daytime guided tours	356	689	1 131	954	1 036	1 179
Astronomy field nights	1	7	10	2	16	24
Field night attendance	3 000	1 488	1 846	150	2 045	1 244
Lectures and talks	21	21	44	64	97	47

Talk attendance	350	825	1 294	1 214	2 191	1 748
Student consultations	0	2	25	36	56	19
Customer satisfaction (star viewing and guided tours, %)	98	97	98	96	98	98
Astronomy awareness raised (%)	97	100	100	96	98	97
Educational quality (%)	98	99	98	96	97	97

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 12–18 months)

- Trial star viewing nights that are wholly run by the Perth Observatory Volunteer Group.
- Adequately house the 76cm aperture telescope—the largest telescope available for public star viewing in the southern hemisphere.
- Evaluate ways of using the two internet telescopes to better support astronomy education in Western Australia.

Astronomical information services

Core function

Team members

R Martin (0.1), A Verveer (0.2), V Smith (0.1), A Williams (0.1), G Lowe (0.3), A Taylor (0.4).

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.

Aim

Provide relevant and timely astronomical information.

Summary of progress (2010/2011) and main findings

- There were nine peer reviewed papers published in scientific journals.
- The *Western Australian Astronomical Almanac* was replaced with a similar Australia wide almanac.
- There were over 260 000 'page viewings' on the Observatory's website.

Activity measures

Activity	10/11	09/10	08/09	07/08	06/07	05/06	04/05
Telephone enquiries	4 972	8 916	4 817**	9 858	13 348	14 655	11 516
Information line	***	1 832	1 031	2 179	3 413	2 935	1 996
Email enquiries	998	494	769	615	777	447	543
Consultations	0	9	38	47	56	36	20
Newspaper, radio & TV	116	109	129	175	201	161	105
www page views (000s)*	260*	244*	323*	404*	1 519	880	709

Positive responses to 'quality' questions in surveys (%)	98	99	98	99	98	98	98
Satisfaction of information requests as they occur (%)	98	99	98	97	95	95	98

*From 07/08, '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.

*** Service no longer provided.

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 12–18 months)

- Liaise with Strategic Development and Corporate Affairs Division to develop a new web site for the Perth Observatory.
- Make further progress towards a self-guided tour by writing fact sheets about the telescopes at the Perth Observatory.

Variable star observations

SPP# 1998-009

Team members

R Martin (0.01), A Verveer (0.05), A Williams (0.05), G Lowe (0.03).

Context

This project represents a long-term worldwide collaboration to study variable stars.

Aim

Monitor the brightness of variable stars to provide increased knowledge of the structure and processes within stars.

Summary of progress (2010/2011) and main findings

- Initiated a search for signs of variability in hot low-luminosity stars that are either white dwarfs or sub dwarf (sdB). This is collaboration between Perth Observatory and astronomers in the Czech Republic.
- A peer reviewed paper describes why a sdB star was misidentified, in 1967, as a planetary nebula. Archival data and some new data are used to identify the star as an ordinary sdB star that is moving through an unrelated HII region of gas. The combination of the two objects mimic the appearance and to an extent the properties of a planetary nebula.

Management implications

Identification of the sdB star refined the criteria necessary to identify planetary nebula and improved the fiducial nature of the sample of planetary nebulae available for study.

Future directions (next 12–18 months)

- Continue participation in variable star monitoring programs.
- Analysis of data and publication of results.

Imaging and spectrophotometry of comets

SPP# 1998-010

Team members

R Martin (0.01), A Verveer (0.05), A Williams (0.01), G Lowe (0.03).

Context

This project involves a long-term collaboration with astronomers from the United States of America in the study of comets.

Aims

- Monitor cometary brightness changes in specific wavelength bands.
- Observe comets over a wide range of heliocentric distances both pre-perihelion and post-perihelion.
- Image the coma and tail(s) for specific structural features.

Summary of progress (2010/2011) and main findings

This project was dormant in 2010/2011 owing to the lack of suitable targets.

Management implications

Observations of comets will facilitate a comparison between the various cometary families and build a database of cometary properties.

Future directions (next 12–18 months)

Partners at Lowell Observatory will undertake high priority observations as opportunities concerning suitable comets arise.

Imaging and CCD photometry of transient and variable sources

SPP# 1998-011

Team members

R Martin (0.01), A Verveer (0.05), A Williams (0.20), G Lowe (0.03).

Context

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-horizon, every eight seconds, in the selected radio frequencies. The MWA is one of two path finder telescopes at the proposed Western Australian site for the Square Kilometre Array radio telescope. Observatory staff are involved in the development of software and electronics for the MWA. One of the proposed areas of research for the MWA is the detection of transient sources.

Aims

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

Summary of progress (2010/2011) and main findings

The MWA consortium published two refereed papers. The first describes the real-time techniques used to produce a 20 degree radio image from MWA data. The second paper describes MWA's low radio frequency observations of the Sun. These low radio frequencies allow the simultaneous observation of spatial and spectral variations. Short period variations were observed (probably for the first time) and identified as new way of depositing energy into the Sun's Corona.

Management implications

Support for the development of MWA contributes to the Western Australian bid for the SKA.

Future directions (next 12–18 months)

Continue to participate in the development of the MWA.

Astrometry of minor planets, comets and targets of opportunity

SPP# 1998-012

Team members

R Martin (0.01), A Verveer (0.05), A Williams (0.01), G Lowe (0.04).

Context

This project involves a long-term worldwide collaboration to track and discover asteroids and comets. Targets of opportunity are also observed as appropriate. The origin of these bodies is of fundamental interest in itself in order to determine the origin, history and fate of each object. Also, knowledge of an object's position facilitates other specialised types of observation (and these not need be restricted to the visible part of the electromagnetic spectrum).

Aims

- Measure the position of minor bodies, so as to determine their orbits.
- Measure the position of targets of opportunity such as supernovae in order to confirm their existence as well as facilitate follow-up observations with other instruments.

Summary of progress (2010/2011) and main findings

This project was dormant in 2010/2011.

Management implications

Astrometric positions are supplied to the Minor Planet Center to refine the orbits of selected asteroids and comets.

Future directions (next 12–18 months)

Continue measuring the position of planets, comets and other targets.

Monitoring gravitational microlenses

SPP# 1998-013

Team members

R Martin (0.3), A Verveer (0.05), A Williams (0.30), G Lowe (0.03).

Context

Members of the PLANET group are distributed worldwide, as is the telescope network, with all planning of the observing strategy for the events being carried out via an online 'homebase' control system based on real-time data reduction and automatic modelling. As the night finishes at one telescope site, the next telescope to the west continues observing so that targets can be observed for 24 hours a day, seven days a week. Members anywhere in the world are able to adjust target selection and sample rates to optimise coverage of ongoing anomalies. The project uses the gravitational microlensing effect to gain information about our galaxy, its stars and their planetary companions. Access to telescopes in Perth, Siding Springs, Tasmania, South Africa, the Canary Islands, Chile, Brazil, and Hawaii (ranging from 0.6m to 2m) allows 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 (2010/2011) and main findings

- Five peer reviewed papers were published this year:
- Another extrasolar planet approximately 2.6 times the mass of Jupiter was discovered orbiting a dwarf star.
- A sample of high magnification microlensing events was used to estimate the frequency of stars that have an outer planetary system that resembles our solar system. This study estimated that if a star Is known to have at least one giant gas or one giant ice planet then that star has a 1/6 chance of having an outer planetary system that is solar like.
- Two papers discussed the observations where the source star is resolved by the microlensing star to the extent that the brightness at the centre of the star is seen to be brighter than the edge of the star. This is called limb darkening. In the first paper spectroscopy was used to classify the source star as a cool M class red giant star. This classification of the star and photometric observations showed that brightness variations across the disk of source star agree with theoretical models. The second paper classified the lensing star as a K giant star using photometry. This paper found marginal disagreement between the temperature of the K giant star calculated from stellar models and the star's surface temperature measured directly from photometric colours. Possible reasons for this difference were discussed.

Management implications

- While there are several techniques for finding extrasolar planets, microlensing searches an entirely different region of parameter-space, with different selection biases, to form a perfect complement to the radial velocity technique and to help determine planet formation mechanisms and the statistics of planetary systems.
- The statistic paper gives insight into the occurance of planetary systems similar to our own solar system.
- Limb darkening observations are a valuable tool and one of the few ways of testing theoretical models of stellar atmospheres.

Future directions (next 12–18 months)

- Finalise papers currently in preparation.
- Continue observations in the May–September 2011 'galactic bulge season'.

Supernova search

SPP# 1998-014

Team members

R Martin (0.3), A Verveer (0.05), A Williams (0.1), G Lowe (0.03).

Context

A long-term study of supernovae are involved in this project—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 (2010/2011) and main findings

- One refereed paper published on supernova SN2008gz. SN2008gz is Type IIP supernova that shows an anomalous magnitude drop in the transition from plateau phase to nebular phase. The nebula phase of SN2008gz was 0.5 to 1.5 magnitudes brighter then a typical Type IIP supernova. This supernova also shares spectral features with the peculiar supernova SN1998a, however, an absence of early observations of SN2008gz precludes it's classification as a peculiar Type II event.
- Software for a new guide camera was developed and installed on the PLAT.

Management implications

Observations of anomalous supernovae facilitate the understanding of the mechanisms of supernova explosions and the supernovae's progenitor stars.

Future directions (next 12–18 months)

Increase the number of supernovae that are photometrically monitored.

Astronomical evaluation of sites in Western Australia

SPP# 2000-006

Team members

R Martin (0.06), A Verveer (0.05), A Williams (0.01), G Lowe (0.01).

Context

The evaluation of various sites regarding their suitability for astronomical observations are the key aspects of this project.

Aim

Test appropriate Western Australian sites regarding their suitability for astronomical observations.

Summary of progress (2010/2011) and main findings

This project was dormant in 2010-2011.

Management implications

Determining the suitability of sites for astronomical observations will provide information necessary for the planning of future facilities.

Future directions (next 12–18 months)

- Observations will be conducted as appropriate.
- Results to be published and SPP to be finalised.

STUDENT PROJECTS PROGRESS REPORT

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 000ha 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 has provided an opportunity to compare the impacts of fire on the biodiversity of their invertebrate communities. Beetle species represent represent 9.9—21.5% of these communities, occur in all trophic guilds, and hence should be responsive bio-indicators of the differing fire seasons and intensities. An additional aim is to compare the impact on beetle biodiversity of a future 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. Ninety-seven morphospecies of these were collected only from the patchy mosaic fire regime and 64 morphospecies collected only from the wildfire regime.

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 is 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 have been translocated from Bald Island to the Angove reserve, near Two Peoples Bay. Habitat features being investigated include 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 in either heartwood yield and 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.

To date, four multi-product genes (terpene syntheses) have been cloned and characterised including the enzyme responsible for production of the santalenes, precursors to the commercially valuable santalols (published in 2011). The next stage of this research seeks to functionally characterize the cytochrome p450s, which exhibit specific hydoxylase activity and, in particular, are responsible for the chemical conversion of the santalenes. Several P450 candidates have been selected from an EST and 454 libraries derived from *S. album* wood tissue. A mixture of *in vivo* and *in vitro* systems will be trialled using both yeast and bacterial host cells. A comprehensive chemotaxonomic investigation is almost complete and a study of the genetic diversity of this species across its natural distribution from regions in the wheatbelt, goldfields, Shark Bay and Carnarvon has commenced. Environmental data including host species and distances, tree height, diameter, soil type and pH, rainfall have also 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. 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**

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-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.

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* subsp. *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 examines 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 will also be examined by comparing response of trees in the drier natural populations with those transplanted to a trial grown in wetter environments.

Field sampling of nine natural populations for morphological and physiological traits has been undertaken with sampling of the plantation trial at Toolibin scheduled for July 2011. Laboratory analysis is currently underway.

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 iron 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 (BIFs), 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 and DNA extraction of the four selected species *Banksia arborea*, *Grevillea georgeana*, *Atelomastix bamfordi* and *Antichiropus Mt Jackson* has commenced and is ongoing. 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.

Scientist: **P de Tores**

Student: *H Grim*

Project title

Possum ecology and health on the Geographe Coastal Plain

Progress

The project investigated naturally occurring populations of ngwayir (western ringtail possum, *Pseudocheirus occidentalis*) and koomal (common brushtail possum, *Trichosurus vulpecula*) at two discrete sites on the southern Swan Coastal Plain between Bunbury and Busselton.

Population density at the two sites was obtained for ngwayir using distance sampling analysis (program 'Distance') of spotlighting data, and for koomal using spatially-explicit mark/recapture software (program

'Density') to analyse trapping data. The population density of both species was higher in the tuart/peppermint woodland compared with the *Banksia* woodland, but the density of ngwayir at both sites was lower than that in the pure peppermint woodland typical of the Busselton coastal strip.

Home ranges were produced by kernel density estimation after calculation of the smoothing parameter using likelihood cross-validation (software 'Animal Space Use'). The repeated use of diurnal rest sites by possums strongly influenced the home ranges produced, with simplified internal range structure and expanded range size, particularly in apparently unused areas. The home range and habitat use results indicated substantial overlap in the use of habitat resources on a spatial basis, within and between species. The results of ngwayir habitat use also indicated a strong inclination for the use of tree hollows when they are available.

Scientist: **P de Tores**

Student: *K Yokochi*

Project title

The efficacy of rope bridges in mitigating negative effects of roads on populations of possums in southwest Western Australia

Progress report

Roads represent a threat to wildlife populations through processes such as mortality, habitat destruction and population fragmentation. Mitigating such adverse effects on wildlife is becoming increasingly important as the rates of wildlife extinction and urban development increase. Rope bridges built over roads connecting vegetation on either side of roads, have been constructed in several locations as a mitigation measure for arboreal species. However, no study has demonstrated their use by multiple individuals, or gene flow as a result of the crossing structures and it is therefore not known if they successfully re-connect the fragmented animal populations. This project aims to assess the effectiveness of rope bridges in mitigating the negative ecological and genetic impacts of roads on the threatened western ringtail possum (*Pseudocheirus occidentalis*) and the common brushtail possum (*Trichosurus vulpecula*) in the Busselton region.

Two rope bridges will be installed; one over Caves Road, linking peppermint (*Agonis flexuosa*) woodland habitat on Busselton Shire managed estate with peppermint woodland habitat within Locke Nature Reserve); the second will traverse a Water Corporation-managed artificial drain and will link peppermint habitat within freehold land with the peppermint woodland habitat within Locke Nature Reserve. Monitoring of radio-collared *P. occidentalis* and *T. vulpecula* to date has recorded two mortality events of *P. occidentalis* where death was a result of a collision with a motor vehicle. Nine mortality events of *P. occidentalis* and one of *T. vulpecula* have been attributed to fox predation within Locke Nature Reserve, despite regular fox baiting.

Scientist: **P de Tores**

Student: *L Zimmermann*

Project title

Population density estimate of western ringtail possums (*Pseudocheirus occidentalis*) at Karakamia Wildlife Sanctuary

Progress report

This research was conducted at Karakamia Wildlife Sanctuary, that is protected by a predator-proof fence. The western ringtail possum (*Pseudocheirus occidentalis*) was previously translocated to Karakamia. Individual *P. occidentalis* were known to be present and a population was thought to have persisted within the sanctuary. The common brushtail possum (*Trichosurus vulpecula hypoleucus*) was also present as a resident, *in situ* population. The population size of both species was not known. Distance sampling methodology was used to derive abundance and density estimates for *P. occidentalis* and *T. v. hypoleucus* within riparian and non-riparian habitat near the initial translocation release site for *P. occidentalis*. Nocturnal spotlighting count data were collected for both species of arboreal possum.

The model which best described the data resulted in population density estimates for *P. occidentalis* of 2.87ha^{-1} and 2.02ha^{-1} for the riparian and non-riparian habitat, respectively. The estimated population size was 11 and 17 adult *P. occidentalis* for the riparian and non-riparian habitats, respectively. The densities of *T. v. hypoleucus* within the riparian and non-riparian habitats were 2.64ha^{-1} and 2.60ha^{-1}, respectively. The coefficient of variation (%CV) was low for each derived estimate. This suggests strong

inference can be drawn from the findings.that indicated the riparian habitat supported a higher density of both species. It further revealed the *P. occidentalis* population had dispersed from the riparian habitat at the original release site into the surrounding non-riparian habitat. This study provided the first quantitative estimates of *P. occidentalis* population size since the initial translocation to the sanctuary.

Scientist: **P de Tores**

Student: *M Rowland*

Project title

Determining habitat use of the western ringtail possum (*Pseudocheirus occidentalis*) in remnant vegetation patches retained within the Dalyellup Beach Estate

Progress report

Dalyellup Beach Estate has been designed to incorporate retention of habitat patches considered suitable for the western ringtail possum (*Pseudocheirus occidentalis*). The patches vary in size and in their floristic and structural composition, and most contain a mix of peppermint (*Agonis flexuosa*), tuart (*Eucalyptus gomphocephala*) and banksia (*Banksia littoralis*, and *B. attenuata*) woodland with the potential to support populations of *P. occidentalis*. However, the conservation value of these retained habitat patches to mitigate the impact of fragmentation and loss of *P. occidentalis* is not unknown. This project is aimed at quantifying survivorship of, and habitat use by, *P. occidentalis* within these patches.

Eighteen *P. occidentalis* have been captured (through use of a purpose built immobilising dart gun) from within five habitat patches. Standard morphometric data were recorded and a movement sensitive (mortality) radio-collar was fitted to each possum. Radio-telemetry procedures are currently being used to collect data on nocturnal and diurnal locations to derive home range estimates, information on habitat use and to determine if there is movement between patches. To date, the majority of diurnal locations have been in tree hollows and dreys. Only two possums have been recorded outside the patch in which they were originally caught. One of these possums, an adult male, has been recorded using diurnal rest sites and nocturnal foraging areas within one patch and recorded using nocturnal foraging areas only in the neighbouring patch. The other possum, a juvenile male was found dead in the patch neighbouring the patch in which it was originally caught. The cause of death was attributed to fox (*Vulpes vulpes*) predation, as inferred from melt curve analysis of DNA recovered from the possum's damaged radio collar.

Scientist: **P de Tores**

Student: *C Love*

Project title

Survivorship, dispersal and habitat use of a population of the western ringtail possum (*Pseudocheirus occidentalis*) left *in situ* during vegetation clearing for urban expansion

Progress report

In situ management of the potentially displaced populations of the western ringtail possum (*Pseudocheirus occidentalis*) has been advocated as an alternative to translocation. This in situ management has included (i) retention of habitat within the development area; (ii) 'encouraging' (shepherding) displaced animals to find refuge in retained and/or neighbouring vegetation; (iii) use of 'possum spotters' to locate and catch displaced possums when clearing is taking place and, once caught, immediately releasing these possums in neighbouring vegetation; and (iv) a 'do-nothing' approach whereby individual animals are assumed to "make their own way" from the cleared area and find refuge elsewhere. None of these in situ strategies has been quantitatively assessed and the fate of *P. occidentalis* displaced as a result of clearing is unknown. This project is part of a pilot study aimed at determining the the effect on *P. occidentalis* from clearing a small area of vegetation known to support a small, albeit unquantified, population of *P. occidentalis* The project will also monitor the dispersal of these possums, should it occur, and the pattern of habitat use in the adjacent vegetation prior to, during and post clearing. A control site, which is not subject to clearing, has also been established in floristically and structurally similar habitat.

Monitoring of survivorship, dispersal and habitat use is being undertaken through conventional radio-telemetry techniques. To date, five *P. occidentalis* have been caught within the area to be cleared and five have been caught within vegetation immediately adjacent. Eight *P. occidentalis* have been caught at the control site. All 18 *P. occidentalis* have been fitted with radio-collars and monitored to record diurnal rest sites and nocturnal foraging areas. One possum caught within the area to be cleared has been

recorded outside this area and only when using diurnal rest sites, in this case dreys. None of the remaining four *P. occidentalis* caught within the area to be cleared has been recorded at diurnal or nocturnal locations outside this area. Diurnal location records for these four possums have included dreys in the mid and upper canopy and rest sites on the ground in coast sword-sedge. None of the five possums caught in habitat adjacent to the area to be cleared have been recorded within the area to be cleared. Two of these five possums were recorded (diurnal records only) using a roof space. Two possums at the control site have been recorded using nest boxes during the day.

Scientist: **J Farr**

Student: *K Ironside*

Project title

Trophic dynamics of predatory invertebrates in jarrah forests of differing fire history

Progress report

This project proposes to use stable isotopes to investigate how historical fire regimes have influenced the trophic relationships of invertebrate communities in jarrah forest ecosystems. It tests the hypothesis that frequent fire increases the incidence of intraguild predation in litter dwelling predatory invertebrate groups. To achieve this, the effect of contrasting fire interval patterns and fire frequency on litter the dwelling invertebrate community as a whole will also be investigated. An inventory of invertebrate fauna will be established to determine if species richness and abundance differ within or between fire treatments. Specimens have been categorised into their respective trophic groups to determine if fire has changed the trophic structure of the communities.

Field work was completed in April 2009 and specimens have been identified to morphospecies taxonomic level. Specimens have been prepared for stable isotope analysis which commenced in June 2009 and is now complete. Data is in the process of being analysed pending project write up.

Scientist: **J 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 *T. copemani* affecting Western Australian native marsupials. Phylogenetic analysis has shown that *T. copemani* is closely related to the South American trypanosome *T. cruzi,* the etiological agent of Chagas disease known to be infective to both a wide variety of animal species and humans. The tick species *Ixodes australiensis* has recently been identified as the vector of *T. copemani*. Motile trypanosomes were found in sections of tick midgut and haemolymph, 49 and 117 days after tick collection, with sequencing showing 100% homology to *T. copemani* (genotype A). Detection of trypanosomes within tick faeces suggests that the transmission of *T.copemani* from vector to host is via the faecal-oral route. The survey to establish the prevalence of blood parasites (trypanosomes and *Theileria*) and gastrointestinal parasites (*Eimeria*, *Giardia* and *Cryptosporidium*) isolated from quokkas from three geographical locations (Two Peoples Bay, Bald Island and Rottnest Island) is still in progress. To date no trypanosomes have been detected in quokkas captured from Rottnest Island. These results show that a 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: **J 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 commoner 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 commoner 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 2009, and a Water Corporation reserve joining Two Peoples Bay Nature Reserve where bush rat, quokka and quenda only, occur.

Samples have been obtained from all sites with continuing trapping to occur in 2011 to obtain further scats for analysis.

Scientist: **L McCaw**

Student: *J Cargill*

Project title

Fate of *Eucalyptus marginata* seed from canopy store to emergence in the northern jarrah forests of Western Australia

Progress report

This project seeks to improve understanding of the factors that determine the success of jarrah seedling establishment following shelterwood harvest in jarrah forest. In contrast to jarrah, marri generally establishes an abundant crop of seedlings following harvesting and burning. Factors being investigated through experimental research include seed availability, seed viability, seedbed receptivity and losses from post-seedfall predation.

Seedfall, seedling emergence and establishments have been monitored following shelterwood burns conducted at Dale and Palmer blocks. Survival from December 2008 until June 2009 was good (>70 %) despite dry conditions persisting into late autumn. An improved seed forecasting system for jarrah has been developed. The thesis was submitted for examination in January 2011.

Scientist: **L McCaw**

Student: *A O'Donnell*

Project title

Fire patterns and vegetation structure in semi-arid woodlands and shrublands in southern Western Australia

Progress report

This study draws on fire history information (including air photo, satellite imagery and vegetation mapping) to investigate fire patterns at the landscape level in the Lake Johnson area in southern Western Australia, where very large fires have occurred at different intervals over previous decades. Research questions include:

- How much of the landscape has been burnt at various frequencies over the last ~50 years for which air photo and satellite imagery records exist?
- How patchy are large fires? Does patchiness reflect effects of weather factors or underlying landscape and vegetation attributes?

- Has fire history induced changes in vegetation structure and can these changes be deduced from comparison of present day vegetation and Beard's mapping (1970s)?
- Can fire-induced boundaries be detected in the field from differences in vegetation structure or species composition (e.g. absence of fire-sensitive obligate seeder species such as *Callitris*).
- Are eucalypt woodlands in decline or is regeneration adequate to provide for long-term persistence and development?

The project will provide information to test hypotheses that: a) fire history has led to structurally degraded vegetation, and b) the proportion of the landscape in different post-fire age classes follows a negative exponential model.

Fire activity has been studied in relation to climatic data, demonstrating that large fire events are associated with drought years during the fire year, preceded by significantly wet and cool conditions during the preceding year.

Papers were published in *Dendrochonologia* on the use of *Callitris* tree rings for dating past fires, and in *Journal of Biogeography* examining the role of vegetation type and fire history in controlling fire spread at the landscape scale. A manuscript examining the relationship between fire activity and climate has also been submitted. The thesis was accepted in May 2011.

Scientist: **L McCaw**

Student: *J Hollis*

Project title

Coarse woody fuel availability and consumption in Australian forest fires

Progress report

The ability to predict the amount and type of fuel consumed during wildfires is important to land and fire managers throughout Australia. Consumption of coarse woody fuels is important for wildlife habitat management and plant regeneration, prediction of radiant heat load on fire fighting personnel and equipment, and for carbon accounting. Factors governing the consumption of fine fuels <6mm diameter are well understood but less is known about the consumption of coarse woody fuel that may smoulder for some time following the passage of a flaming fire front.

Experimental fires have been completed at three sites in south-west Western Australia (Wilga, Quillben, Hester) and two fires at Tallarook in central Victoria. An extensive fuel consumption data set gathered in conjunction with Project Aquarius fire experiments in Western Australia during 1983 has been validated and incorporated into an evaluation of existing fuel consumption predictive models. A paper describing this work has been accepted for publication in *Forest Ecology and Management*.

Relationships between woody fuel consumption and fire intensity have also been investigated using data from the experimental fires, and data gathered following intense wildfires including the 2005 Perth Hills fire and the 2009 Black Saturday wildfires in Victoria. Findings from this work were published in *Australian Forestry* and two papers examining the ability of existing models to predict woody fuel consumption, and key factors affecting fuel consumption have been published in *Forest Ecology and Management*. The thesis was submitted for examination in March 2011.

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 prepared.

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 southern-hemisphere phylogeographical studies, 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 Pleistocene distributional changes in species. Banded ironstone 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 examines the phylogeography of two midwest *Acacia* species, *Acacia karina* and *A. cockertoniana,* which have distributions centered on BIF ranges, in order to test the hypothesis of BIF ranges as refugia. This work aims to assess the levels of chloroplast variation in the two study species, identify any major evolutionary divergences or disjunctions across their range, and examine whether individuals on low hills and plains adjacent to the BIF ranges are derived from individuals in higher elevation BIF populations.

Scientist: **K Morris**

Student: *J Dunlop*

Project title:

Factors affecting fauna translocation success

Progress report

Fauna translocations, particularly to mainland sites, have a low rate of success (<20%). Loss of founders to introduced predators has usually been the main reason for this. This project aims to assess the role other factors such as disease and parasite loads, founder genetic variability, founder size and founder source may have on translocation success. Data collection commenced with the arrival at Lorna Glen of translocated boodies from Dryandra in January 2010 and boodies and golden bandicoots from Barrow Island in February 2010. Each animal was assessed for reproductive condition and body condition. DNA samples were taken from a large proportion of the founder population to quantify genetic diversity and ensure that following generations do not suffer significant bottlenecks. Blood samples were taken where possible, for basic health parameters such as white and red blood cell counts, and detection of haemoparasites. Ectoparasites were collected when present. Half of the population receives anti-ectoparasite treatment whenever captured in order to manipulate the presence of haemoparasites in these animals and determine whether there is a follow-on effect of improved condition and/or reproductive success.

Results so far have indicated that the animals are healthy and have greatly reduced their ectoparasite load since being moved from Barrow Island (both treated and untreated groups). The animals from Barrow Island have gained weight and are highly reproductive. The boodies have lost approx 25% of their initial weights and stabilised, presumably reflecting a return to a ‘healthy’ body weight after being overweight in the captive colony. Monitoring has shown 13 animals (11 boodies and two bandicoots) have died, detected via radiotelemetry, and 20 new animals (four boodies and 16 bandicoots) have been recorded in the population and microchipped so far.

Another aspect of this project is to examine the historic role disease may have had in the decline of mammals. We are currently working toward developing successful methodology for detecting haemoparasites (trypanosomes and toxoplasma) from old museum skin specimens. Parasite DNA extraction methodology will be tested on some non-vital museum woylie skins, since woylies are a

species that has shown high prevalence for trypanosomes in previous studies and are likely to give a positive result. When these are successful, we will be in a good position to approach other museums and ask to take samples of older and more valuable specimens.

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

During winter 2010 two experimental translocations were setup in the south coast region. One involved the translocation of ca 500 seedlings of *Banksia ionthocarpa* subsp. *ionthocarpa* in Kalgan Plains Nature reserve. This translocation will test the effect of microhabitat (bare ground, open heath, closed heath), watering (irregular handwatering versus automatic weekly irrigation), time of transplantation (early May versus early July) and growth medium (sand versus potting mix) on the survival of seedlings. The other translocation involved the transplantation of ca 850 seedlings of *Acacia awestoniana* in Stirling Range National Park. This experiment will test the effect of microhabitat (under wandoo as opposed to in the open), watering (no watering, handwatering and automatic watering), and growth medium (sand versus potting mix) on the survival of seedlings. In both experiments seasonal soil water status measurements as well as measurements on the physiological activity of individual seedlings will complement the mortality and growth assessments. So far more than 80% of seedlings of both species have survived their first summer. Future work will involve a comparison of *A. awestoniana's* drought and temperature tolerance with a range of range restricted and common *Acacia* species.

Scientist: **I Radford**

Student: *A Cook*

Project title

Can mosaic burning protect northern quolls from severe wildfires in the north Kimberley?

Progress report

This project formed part of the major research and monitoring program being conducted in the north Kimberley region, which is a detailed investigation of density, fecundity and survivorship of critical weight range mammals in relation to current fire regimes. The study was conducted at the Mitchell Plateau in the north Kimberley where large areas frequently experience broad-scale intense wildfires. This project investigated habitat use and home range movements of northern quolls (*Dasyurus hallucatus*). The northern quoll remains abundant in several areas of the north Kimberley and is a suitable species for detailed investigation of landscape/habitat and resource use in the context of fire mosaics as it is a major native predator ranging over relatively large territories.

Differences in home range area appear to be related to seasonal effects rather than fire. Quolls were not displaced by the fire event and the home ranges of two individuals radio-tracked prior to and after the fire were entirely within the burnt area. This study was conducted in a landscape where fire is a regular occurrence and investigated the effect of a relatively low intensity fire in the mid dry season (June) when environmental conditions are considered less stressful than later in the year. Results indicate that northern quolls are able to tolerate fires under these conditions but the response may have been quite different if the fire occurred later in the season. Of 15 males investigated it was confirmed that nine had survived beyond the breeding season. Four of these were confirmed to survive to their second breeding season.

The Masters thesis was accepted with minor amendments in March 2011, and a poster paper was presented on this research at the Australian Wildlife Management Society Conference.

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 is to characterise, from a molecular taxonomic perspective, undescribed *Phytophthora* taxa occurring in natural ecosystems in Western Australia, and to formally describe three of these new species (*Phytophthora* sp. 2, *Phytophthora* sp. 1, *Phytophthora* sp. 9). The pathogenicity of these three species will also be assessed.

Progress has been made on the description of two more novel taxa of *Phytophthora*, and the coalescent analysis focussing on *P. multivora*.

The description of two taxa, *P. arenaria* (previously referred to as *Phytophthora* sp. 1) and *P. constricta* (*Phytophthora* sp. 9), has been accepted for publication in *Plant Pathology*. The description of *P. elongata* (*Phytophthora* sp. 2), titled "*Phytophthora elongata* sp. nov., a novel pathogen from the *Eucalyptus marginata* forest of Western Australia", was published in *Australasian Plant Pathology*.

The sequencing of four nuclear and two mitochondrial loci for isolates of *P. multivora*, *P. citricola sensu stricto*, *P. citricola* E, *P. citricola* 1, *P. plurivora*, and five other closely related isolates from Intergenic Spacer Region (ITS) clade 2a is complete and phylogenetic and coalescent analyses have begun. Analysis to date shows that there is greater nucleotide and haplotype diversity amongst isolates of *P. multivora* from South Africa than from Western Australia, with no significant difference between populations (defined by geographical location) with the exception of the mitochondrial nadh1 locus, for which the difference between South African and Western Australian populations is significant.

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 in relation to factors such as vegetation structure and floristics, position in the landscape, landform systems and geomorphology; 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.

A rapid survey technique was devised by Graeme Liddelow to provide a qualitative measure of relative abundance (high, medium, low) of quokkas, using indicators of activity including runnels, tracks, faecal pellets and sightings. In 2009, the accuracy of this rapid survey technique was evaluated by comparing relative abundances obtained from the rapid survey with abundance estimates obtained through established methodologies for the estimation of populations, including web based trapping and transect based counts of runnels, tracks, faecal pellets and sightings. It was found that the rapid survey technique was very effective at determining presence of quokkas but made inaccurate assumptions about currency of occupancy and the relative abundance of animals, resulting in an over-estimation of population size. The hypothesis that indices of activity can be used in a rapid survey to quantify population abundance for quokkas in the southern forests of Western Australia is supported, but only for indicators of activity that are readily detected and for which recency of occupation can be determined. A rapid survey of fresh faecal pellet groups was found to provide a reliable and practical estimation of population abundance.

Surveys of quokka abundance and collection of habitat data from has been completed at 130 sites within the southern forests between Manjimup and Walpole. Habitat occupancy models will be fitted to the data in an effort to predict occupancy patterns in the southern forests of Western Australia based on

habitat characteristics. Surveys and monitoring to date suggest that groups of quokkas in the forests south of Manjimup are more fragmented than expected and that densities of animals are quite low. The condition of animals has varied quite considerably depending on the season and food availability.

Trials of GPS collars found no evidence of adverse effects on quokka welfare or behaviour *in captivity* beyond the initial signs of discomfort by some individuals. Upon deployment of the collars in the field, considerable and sustained weight losses were recorded for all collared individuals and a decision was made to discontinue their use due to ethical concerns. Radio collars have since been fitted to 16 animals in a jarrah forest ecosystem and habitat use and movement pattern data have been collected.

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 the Intergenic Spacer Region (ITS) were used for the detection method. The genetic characterisation of *Bartonella* species was established by the multilocus sequences analysis. A novel *Bartonella* 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 the ITS revealed that this isolate is a distinct *Bartonella* species and related to *Bartonella australis* previously isolated from kangaroos in the eastern states. Another *Bartonella* species was detected from ticks (*I. australiensis*) 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 *Bartonella* 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. Research is ongoing, with one paper currently in review and several in preparation.

Scientist: **A Wayne**

Student: *C Pacioni*

Project title

A conservation conundrum: the population and epidemiological dynamics associated with recent decline of woylies (*Bettongia penicillata*) in Australia.

Progress report

This research project aimed to contribute to the knowledge on the general health and ecological attributes of woylie populations that were considered directly relevant for the conservation and recovery of the species. A haematological investigation was carried out and reference ranges were established. Based on the results of a disease risk assessment, selected viruses were ranked as high priority and the serological response to Macropod Herpesvirus, Encephalomyocarditis virus and Orbivirus (Wallal and Warrego serogroups) was investigated. There was no serological evidence of any of the tested viruses affecting woylie populations.

Genetic profiles of indigenous and translocated woylie populations were examined and genetics does not appear to be a contributing factor to the present decline. Nevertheless, particular concern was raised that indigenous and translocated populations, have a substantially reduced genetic diversity. Important insights were gained into woylie population structure and dynamics through analysis of molecular data and the mtDNA analysis, including evidence of historical connections between indigenous populations, which not longer exist as result of the habitat fragmentation caused by agriculture land use.

Lastly, a population viability analysis (PVA) was developed and available for the evaluation of different management strategies. Additionally, the PVA model demonstrated that the main threatening process is the result of the interaction of various variables (particularly predation and inbreeding) that acquired a

considerable strength together, whilst not being greatly significant by themselves. It also quantified the minimum mortality rates that are necessary for the decline to occur.

The PhD was awarded in late 2010. Two papers have been published in *Australian Mammalogy*, and in *Journal of Zoology*, and further publications from this research are in review and in preparation.

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*, including 26 woylies, ten ravens, eight quokkas, 23 ringtail possums, five brushtail possums, eight bandicoots, 16 kangaroos (three species), 22 chuditch, 11 brushtail phascogales, eight cats, five barn owls, four numbats, three rabbits, two bilbies, two foxes, two feral pigs, two water rats, and one each of echidna, western pygmy possum, tawny frogmouth, bush rat, tammar wallaby, mardo, dunnart, and penguin. Markers specific for gene loci B1, SAG1, SAG2, SAG3, SAG4 and GRA6 have been assayed for all samples. Extensive optimisations were carried out to select the right gene markers suitable for Western Australian wild animal samples. Reproducible results were obtained from the optimisation procedures. 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% (103/137). 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. Part of the research outcomes was presented at the World Association for the Advancement of Veterinary Parasitology 22nd International Conference. A paper presenting these results has been submitted for publication.

Scientist: **A Wayne**

Student: *G Yeatman*

Project title

Population demographics of a fenced population of woylie (*Bettongia penicillata*)

Progress report

This project aims to investigate changes in demographic parameters of the woylie population (*Bettongia penicillata*) at Karakamia Sanctuary between 1995 and 2010 in response to increased density. Information will be collated from regular trapping regimes conducted at Karakamia between these years. Specific aims include identifying whether increases in density reduce individual body condition; investigating if there has been a switch to seasonal breeding over time; investigating if there has been a change in sex ratio and whether increased density affects home range behaviour.

Radio tracking was conducted between January and May. Nest and foraging ranges have been calculated for six woylies and preliminary analyses suggest a threefold increase in these parameters compared to other published estimates of woylie home range. Trapping data between 1995 and 2010 has been collated and initial results do not reveal changes in sex ratio with increased density.

An Honours degree was awarded in 2010 and a PhD on wildlife ecology in the Perup Sanctuary recently commenced. This will examine the responses of small vertebrates to different habitat types and a predator-free sanctuary environment and examine factors related to the abundance of woylies throughout the upper Warren region.

Scientists: **A Wayne and N McKenzie**

Student: *P Webala*

Project title

Bat community structure and habitat use across disturbance regimes in jarrah forests, south-west Western Australia

Progress report

The project investigates bat community responses to jarrah forest logging in south-west Western Australia. This involved assessing habitat use of foraging and commuting bats (measured as bat activity) in different logging histories (recently logged, young regrowth and old regrowth sites) using of Anabat bat detectors. The second major component involved the study of the roosting and foraging ecology of two bat species, namely; the southern forest bat *Vespadelus regulus* and Gould's long-eared bat *Nyctophilus gouldi.* The entire project was undertaken by means of radio-telemetry, roost site characterisation, vegetation assessments and measures of insect abundance.

The activity of different bat species related in different ways to structural parameters of vegetation, generally reflecting bat echolocation ability and manoeuvrability. Bats tended to use tracks more than off-track locations, thereby avoiding clutter. At the same time, tracks recorded similar activity across logging histories. However, off-track activity in old regrowth was significantly greater than either young regrowth or recently logged forest. Two species, *Vespadelus regulus* and *Nyctophilus* sp. were more active in old regrowth than other logging histories. Similarly, *V*. *regulus*, *Nyctophilus* sp., *Chalinolobus gouldii*, *C*. *morio* and *Falsistrellus mackenziei* activity was significantly greater on-track than off-track, but this activity was similar on-track across forest types, suggesting bats' use of forest tracks was unaffected by logging. As an indication of the association of low bat activity off-track with clutter, negative relationships of under-storey clutter were the most consistent predictors of bat habitat use. Conversely, reduced clutter and abundant roost resources seemed the most likely explanations for greater activity at old regrowth sites.

There were inter-specific similarities and differences in the selection and location of roosts between *V*. *regulus* and *N*. *gouldi*. Both species were highly selective, preferring old large trees at intermediate or advanced stages of decay, crown senescence and deterioration with a lower percent bark cover as roost sites compared to random trees. Both species also selected hollows for roosting, with *V*. *regulus* roosting exclusively in hollows but a few *N. gouldi* bats also used roosts under decorticating bark, cracks and under the skirt of balga (*Xanthorrhoea preissii*) grass trees. *Vespadelus regulus* preferred tall trees in the canopy with roost entrances higher above the ground with little surrounding vegetation while *N*. *gouldi* preferred roosting closer to the ground and in dense clutter. In general, little evidence was found of bats roosting in eucalypt regrowth, in neither shelterwood creation nor gap release silvicultural treatments, although a few *N*. *gouldi* bats roosted in retained habitat, or remnant, trees in these forest types.

Two papers from this research have been published in *Forest Ecology and Management* and in *Journal of Applied Ecology*. The thesis was accepted in June 2011.

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). Preliminary results indicate fungi consistitute the dominant dietary component throughout southwestern Australian populations but also include 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 paper has been published from this work in *Australian Mammalogy*. The thesis and further papers are being drafted.

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.

A research proposal has been written and presented at the annual post-graduate conference at the Australian National University. A review paper on the importance of population variation in seed and seedling traits is currently in preparation. Data-loggers to monitor soil temperature and moisture have been installed in the field at 24 sites across the south coast of Western Australia from Northcliffe to Cape Arid. Seed has been collected from each of these sites (four species, six populations). Laboratory experiments into temperature thresholds and optima looking at seed germination over the range of temperatures from 5 to 40^{o}C have commenced. A large field experiment has been established on the south coast Western Australia using rain-out shelters and open-top chambers. More than 11 500 seeds have been planted in raised garden beds with irrigation at the site.

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 behavior (survivorship, growth and fecundity) under projected climate change using experiments which manipulate rainfall and temperature. The research is being undertaken in the diverse kwongan heath vegetation on the Eneabba Sandplain a nationally recognized bidoversity hotspot which is projected to become warmer and drier.

In winter 2010, four sites were selected that represented characteristic states of the sandplain environment across different topographies and fire histories: a combination of dune and swale sites, and recently burnt and unburnt sites. Within each site (burnt and unburnt dune, burnt and unburnt swale) three replicated rainfall manipulations were established. These were: no tratement ambient (control); 40% reduction in ranfall (rain-out); and 40% increase in rainfall (rain-on).

The potential impacts of increased temperature are being investigated with open top chambers following the international standard design. Seven chambers were located in each site, around mature vegetation in the unburnt sites, and around seedlings in the burnt sites. Due to the patchy nature of the recent fire at the burnt sites, there was very limited seedling emergence last spring. Therefore this winter the chambers in the burnt sites will have seeds sewn in them, and the emergence and establishment measured. Temperatures within treatments are being measured with ibutton sensor arrays. The growth (height and branch measurements) and reproduction (flower and fruit counts) of woody species within the experimental treatments are being monitored.

Scientist: **C Yates**

Student: *R Thomas*

Project title

Ecohydrological equilibrium theory and *Banksia* woodland vegetation

Progress report

This project is part of a greater study about predicting the impacts of climate change on biodiversity and ecosystem function in the biodiverse shrublands of the Eneabba sandplain. Previous research into

applying ecohydrological equilibrium theory to *Banksia* woodland vegetation had identified community and species level structural relationships with hydrological gradients at the local scale. This project will expand previous research to assess intraspecific variation in ecohydrological habitat requirements at the biogeographical as well as local scales.

The Eneabba study site represents the drier end of the ecohydrological range of *Banksia attenuata* and already has the necessary instrumentation to provide a detailed account of plant interaction with available water sources. Other (wetter) study sites within the range of *B. attenuata* (and possibly other more mesophytic species of *Banksia*) will be contrasted with the Eneabba population to quantify the functional, ecohydrological habitat range for the species. The impact of prospective climate change on the Eneabba ecohydrological habitat of each study species will be represented by the spatial and temporal shift in available water and plant functional response. Structural aspects of site vegetation (physiognomy, leaf area index, cover, sapwood area) will also be related to ecohydrological habitat in a bid to model long-term vegetation response to altered water availability.

20110421-0911-200