UNDERSTANDING MULGA








This proposal details a three year multidisciplinary study of Mulga (Acacia aneura and its relatives) to resolve the complex patterns of variation within this large and important group or Wattles. The benefits derived from an improved understanding of Mulga will be immediate and substantial, and will enable these species and communities to be better-protected, more effectively managed and sustainably utilized. The study will deliver numerous scientific and applied outcomes that are particularly relevant in rangeland areas where competing land use interests may occur.

PROJECT PROPOSAL

Bruce Maslin & Stephen van Leeuwen
CALM Science Division

UNDERSTANDING MULGA

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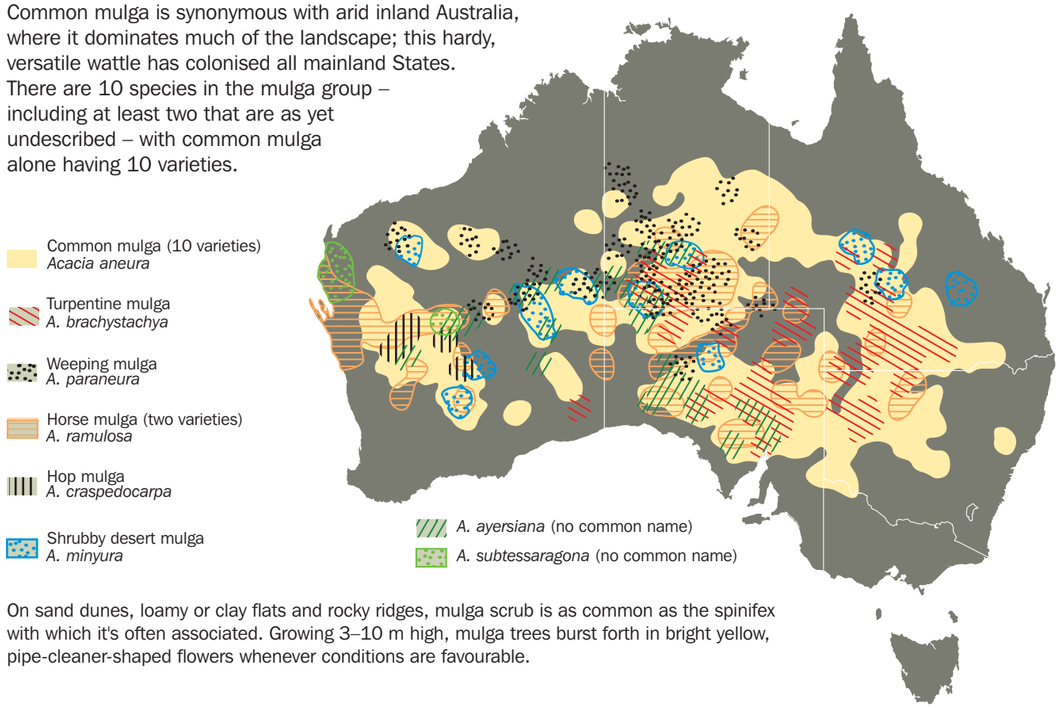
THE MARCH OF MULGA

Common mulga is synonymous with arid inland Australia, where it dominates much of the landscape; this hardy, versatile wattle has colonised all mainland States. There are 10 species in the mulga group – including at least two that are as yet undescribed – with common mulga alone having 10 varieties.



AG CARTOGRAPHIC DIVISION
Source: *Flora of Australia*, Volume 11 (to be published by Australian Biological Resources

On sand dunes, loamy or clay flats and rocky ridges, mulga scrub is as common as the spinifex with which it's often associated. Growing 3–10 m high, mulga trees burst forth in bright yellow, pipe-cleaner-shaped flowers whenever conditions are favourable.

Species currently recognized as comprising the Mulga group – APPENDIX 1

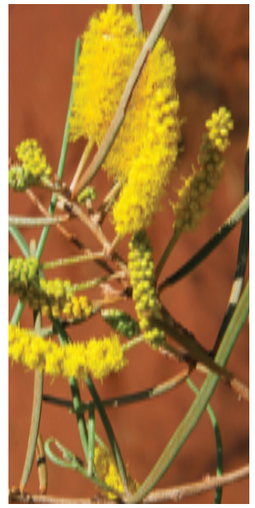
THE MULGA 'CORE GROUP' SPECIES

Botanical name	Common name	State distribution
Acacia aneura F.Muell. ex Benth.		
var. *aneura*	Common Mulga	W.A., N.T., S.A., N.S.W., Qld
var. *argentea* Pedley		W.A.
var. *conifera* Randell	Christmas tree Mulga	W.A., N.T., S.A., Qld
var. *fuliginea* Pedley		W.A.
var. *intermedia* Pedley		W.A., N.T., S.A., N.S.W., Qld
var. *macrocarpa* Randell		W.A., S.A.
var. *major* Pedley		W.A., N.T., S.A., N.S.W., Qld
var. *microcarpa* Pedley		W.A., N.T., S.A.
var. *pilbarana* Pedley		W.A.
var. *tenuis* Pedley		W.A., N.T., S.A., N.S.W., Qld
Acacia ayersiana Maconochie	Uluru Mulga	W.A., N.T., S.A.
Acacia minyura Randell	Shrubby Desert Mulga	W.A., N.T., S.A., Qld
Acacia paraneura Randell	Weeping Mulga	W.A., N.T., S.A., Qld

SPECIES CLOSELY RELATED TO THE MULGA 'CORE GROUP'

Botanical name	Common name	State distribution
Acacia atopa Pedley		W.A.
Acacia brachystachya Benth.	Umbrella Mulga, Turpentine Mulga	W.A., N.T., S.A., N.S.W., Qld
Acacia clelandii Pedley	Cleland's Mulga	W.A., N.T., S.A.
Acacia craspedocarpa F.Muell.	Hop Mulga	W.A.
Acacia ramulosa W.Fitzg.		
var. *ramulosa*	Bowgada, Horse Mulga	W.A., N.T., S.A., N.S.W., Qld
var. *linophylla* (W.Fitzg.) Pedley		W.A., S.A.
Acacia subtessaragona Tindale & Maslin		W.A.

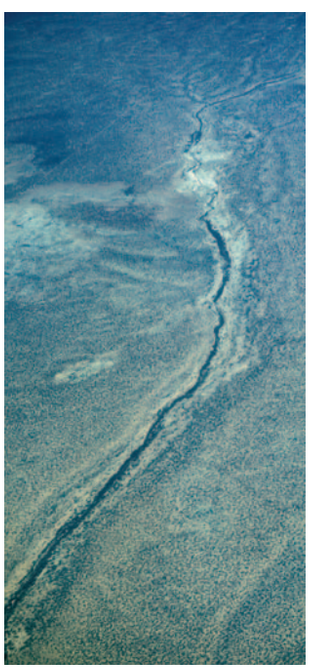
Acacia aneura var. *aneura*. Superficially most Mulga inflorescences look very similar, however, there are some cryptic differences in calyx characters that help identify Mulga types.



CONTENTS

EXECUTIVE SUMMARY

Mulga (Acacia aneura and close relatives) occupies about 20% of arid Australia and is a 'keystone' group that dominates a large portion of the Western Australian rangelands. Mulga communities are repositories of significant productivity and biodiversity, they are resource "hotspots" because of their ability to capture, retain and cycle precious sediments, nutrients and water. Therefore, the effective management of Mulga is critically important for sustainable land use planning and natural resource management, particularly in areas where applied land use interests (such as pastoral and mining) may compete with biodiversity interests. However, a major constraint to the development of management actions that will deliver both biodiversity and sustainable land use outcomes beneficial to the rangelands is a lack of taxonomic clarity in respect to Mulga. This is well illustrated in the Pilbara where government environmental regulators have placed restrictions on certain mining activities because of their inability to confidently assess the conservation status or ecological impacts on Mulga communities because of uncertainties concerning the species.



Extensive Mulga lands near Lake Austin.

As currently defined Mulga comprises 10 species with one, *A. aneura*, containing 10 varieties. Many of these species are extremely variable, their taxonomic boundaries are vague, and identification of the different types is extremely difficult. The situation is further complicated by the existence of numerous hybrids and other entities of unknown taxonomic affinity. The variation observed in Mulga occurs both within and between populations and often results in a very complex mosaic of mixed Mulga communities across the landscape. The factors responsible causing and maintaining this variation are poorly understood, but recent studies suggest that, apart from hybridity, polyploidy, apomixis and neoteny may be involved.

The aim of this proposal is to elucidate the patterns of variation in Mulga and to provide a reliable means of identifying the taxa (i.e. species and varieties). The underlying rationale is that in the absence of appropriately circumscribed and named entities, the information that is assembled and disseminated about Mulga taxa and communities has the potential of being meaningless, or its value significantly diminished. Furthermore, without a sound classification and a reliable identification key, it is in impossible to make comparisons or generalizations about Mulga across the rangelands.

The accrued benefits from an improved understanding of Mulga will be immediate and substantial. This knowledge will enable Mulga species and communities to be better-protected from environmental perturbations, to be more effectively managed and sustainably utilized, will facilitate the identification of high priority areas for conservation together with other land uses and will lead to significant capacity-building within rangeland user communities that will result in numerous benefits such as:

- Increased capacity for land managers to implement programs to mitigate threats and/or reduce pressures on Mulga and the environment. This will result from developing a better understanding of how different Mulga types and communities respond to environmental perturbations (drought) and threatening processes (inappropriate fire regime).
- Better enable land managers and regulators to develop, assess and approve land use plans while ensuring appropriate biodiversity conservation outcomes. This will result from an improved understanding of the distribution and conservation status of Mulga by distinguishing between widespread, common species and those with restricted geographic ranges.
- An increased capacity throughout the pastoral estate to sustainably utilize Mulga. This will occur because the responses of different Mulga types to pastoral land management practices (e.g. prescribed burning) and grazing can be quantified and used in the development of whole-of-station management plans.
- Greater certainty for land rehabilitation practitioners to implement rehabilitation programs and attain completion criteria because the ecological requirements of different Mulga types can be quantified and addressed through the design of site rehabilitation programs aimed at creating self perpetuating Mulga ecosystem.
- Better insights into the biological basis for differences in the traditional uses of different Mulga types and potentially the resolution of uncertainty in respect to the ethnobotanical use/potential of these types.

The accrued benefits from an improved understanding of Mulga will be immediate and substantial.

These benefits are aligned with numerous Federal and State government initiatives designed to promote sustainable land use and biodiversity conservation across the Australia rangelands and have direct relevance to current/proposed research and applied management activities in Western Australia rangelands.

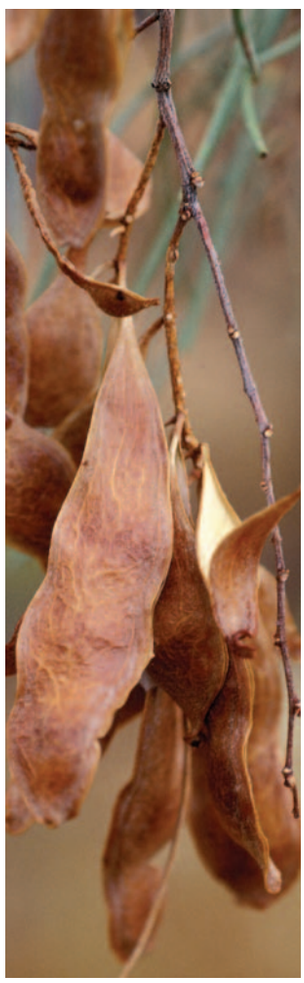
The study will deliver numerous scientific and applied outcomes that will be beneficial for land management across the Western Australian rangelands (with flow-on benefits for rangelands across the continent).

The main deliverables will be:

- Production of a 'Mulga Manual' accessible to the whole community that will comprehensively describe, discuss and illustrate the different Mulga entities. The Manual will be produce in hard copy and will be made available across the World Wide Web. A simplified version of the Manual targeting non-specialist users will also be produced.
- Production of a user-friendly, electronic identification key enabling Mulga types to be easily and reliably named. This will be made available on CD and via the World Wide Web.
- The most comprehensive taxonomic treatment of Mulga ever undertaken.
- Determination of the genetic factors responsible of causing and maintaining diversity within the Mulga group.
- Provision of direction for future biological and ecological studies of Mulga so that the species and its congeners may be effectively managed, conserved and sustainably utilized.
- Peer-reviewed scientific publications describing new species of Mulga and detailing genetic systems operating within the group.
- Assessment of the conservation status of Mulga taxa in Western Australia.
- A basis for understanding Mulga across its entire geographic range within Australia.
- Promotion of the project and its sponsors in CALM's *Landscope* journal and on the web through the *WorldWideWattle* website.

This project is a collaborative one that will employ best-practice genetic and taxonomic techniques. It will by led by Mr B.R. Maslin (CALM) who has worked for almost 40 years on the taxonomy of *Acacia* and who is recognized both nationally and internationally for this work. The genetic program will employ both microsatellite and DNA sequencing techniques and will be conducted by Dr J.T. Miller (University of Iowa, USA) and Dr. M. Byrne (CALM). Complementary studies of anatomy (by Dr R. Rutishauser, University of Zurich), ontogeny and apomixis will also be conducted. Extensive field studies will be undertaken in the principal target areas for the project, the Pilbara and northeastern goldfields regions.

The three year time-frame for the project recognizes the taxonomic complexity of Mulga and the extensive geographic range that these species occupy. The taxonomic and genetic components of the study are very labour-intensive and most of the budget is required for personnel associated with these activities. The time-frame also allows for vagaries of flower/fruit production in Mulga (which is rainfall-dependent). A detailed work schedule for Year 1 of the project is provided and indicative schedules for Years 2 and 3. The total cost of the project is $1 516 004 of which CALM and the University of Iowa will be contributing $944 007 (in-kind and cash contributions). The in-kind contribution will include the expertise of an experienced taxonomist (Maslin), two geneticists (Miller and Byrne), an anatomist (Rutishauser) and a field technician (Fairman). The total budget being sought through sponsorship for the three years is $571 997 and is broken down thus, $195 598 (Year 1), $184 655 (Year 2) and $191 744 (Year 3).



Acacia paraneura (Weeping Mulga). Pods are distinctively large and possess a narrow, marginal 'wing'.

The study will deliver numerous scientific and applied outcomes that will be beneficial for land management across the Western Australian rangelands

BACKGROUND

Mulga (*Acacia aneura* and close relatives) is a 'keystone' group of woody, perennial plants that dominate a large portion of the Western Australian rangelands (Pilbara, Gascoyne, Murchison, Goldfields and Nullarbor). Nationwide Mulga occupies about 20% of arid Australia, with the species occurring in all mainland States. Mulga communities are critically important to the ecology, functioning and viability of rangeland landscapes. They are the resource 'hotspots' of the rangelands as a consequence of their inherent ability to capture, retain and cycle precious sediments, nutrients and water resources. Consequently, these Mulga-dominated 'hotspots' are also the repositories of significant productivity and biodiversity, a characteristic that in the past was appreciated by indigenous Australians and is today reflected in the importance placed on Mulga by the pastoral industry. To ensure that this productivity and biodiversity is maintained, policies and strategies (reservation, off-reserve conservation, station plans, Natural Resource Management (NRM) Investment plans) have been implemented to promote sustainable land use and thus protect Mulga. With continued development and diversification across the rangelands, especially in respect to the region's mineral wealth, the management of Mulga for numerous and sometimes competing interests (cultural, conservation, pastoralism and mining) has become critically important for sustainable land use planning and natural resource management. A key impediment to the development of plans and management actions designed to protect Mulga and to deliver biodiversity and sustainable land use outcomes that are beneficial to the rangelands is a lack of taxonomic clarity in respect to Mulga.

Mulga species are extremely variable, their taxonomic boundaries are poorly understood and identification of the different types within the complex is extremely difficult. Conservatively Mulga comprises 10 species with one, A. aneura, containing 10 varieties (see Appendix 1). Numerous Mulga hybrids also exists that adds substantially to these numbers. Understanding variation within Mulga and its causal factors, and providing a reliable means of identifying the taxa, are critically important because this provides the sound scientific foundation upon which management, utilisation and conservation rests. Such knowledge will enable Mulga species and communities to be better-protected from environmental perturbations, to be more effectively managed and sustainably utilized and will facilitate the identification of high priority areas for conservation together with other land uses. This in turn will lead to significant capacity-building within rangeland user communities that will have numerous benefits as detailed in the Executive Summary above.

The project will adopt a multi-disciplinary collaborative approach to elucidate the variation in Mulga, and to provide a reliable means of identifying the taxa. It will utilize the most modern genetic, anatomical and taxonomy methodologies and provide critical new data on this invaluable biological resource.

Mulga community near Meekatharra

RATIONALE

This project is of critical importance to the management and sustainable use of the rangelands, especially during this period of unprecedented mineral development because:

a) Unless Mulga types are meaningfully circumscribed then any information that is assembled or disseminated about the species or communities has the potential of being meaningless, or its value significantly diminished.

b) Unless Mulga types have names then for practical purposes they do not exist and consequently it is impossible to make comparisons or generalizations across the rangelands.

c) Effective management, conservation, and utilisation of biodiversity depends upon having well-defined, named taxa, and it is imperative that an efficient and effective means be provided that enable users to gain access to these names and hence to the information that is attached to them.

Without this project, and in the absence of a workable resolution to facilitate the discrimination of Mulga types, uncertainty exists and is likely to increase with respect to the continued development and sustainable utilisation of the rangeland. This situation may arise because:

a) Major resource developments and sustainable agricultural initiatives will proceed with ineffective or impaired environmental planning, or conversely, such project will stall or be rejected because of uninformed/inappropriate assessments.

b) Appropriate reservation options may be overtaken by development decisions if Mulga communities having high priority are not identified. (A strategic basis for identifying and protecting specific Mulga assets is urgently needed.).

c) It is not known if there exist threatened Mulga types that require urgent management action.

d) Deliverables from projects currently in progress in the rangelands will be impaired or otherwise compromised and of little comparative value if they do not identify the different Mulga types being studied.

Effective management, conservation, and utilisation of biodiversity depends upon having well-defined, named taxa

Mulga grove near Meekatharra. These localized areas of species richness can have 15 or more different Mulga types growing together.

PILBARA: AN EXAMPLE

The Mulga issue and the uncertainty it confers to natural resource management and sustainable development of the rangelands for various land uses including conservation, pastoralist and mineral development, is well illustrated by the Pilbara region of Western Australia.

Within the Pilbara Region as defined by the Biogeographical Regionalisation of Australia, there are at least 12 different formally described Mulga types. Seven of these are recognised as varieties of *Acacia aneura,* while the other taxa are closely related allies. Additionally, it is estimated that up to another 10 Mulga entities occur in the region but it is not know if these are genuine species, hybrids or some form of genetic backcross. Mulga is at the north western limit of its continental geographic range in the Pilbara, but within the region it is very common and dominates many communities from the Chichester Range southwards. While most Mulga communities appear to consist of a complex mix of different types, some are dominated by only one or two types. The diversity of Mulga is at its greatest within the Hamersley Range and adjacent Fortescue Valley, for example, at West Angelas in the central Hamersley Range 20 different Mulga types have been recorded.

Identification and delimitation of these different Mulga types is very problematic because of considerable variation in morphological characters, particularly phyllode attributes, and the inherent unavailability of pods which provide critical diagnostic characters. Nevertheless, some types can be tentatively identified by their growth form and the position they occupy within the landscape. For example, the Mulga that predominates on the heavy alluvial flats in the Hamersley Range may be *A. aneura* var. *pilbarana*. This variety is ecophysiologically unlike most other Pilbara Mulgas in that it can withstand extended periods of water logging; other Mulga types that grow upslope on more gravely pediments quickly senesce when the habitat becomes waterlogged (as happens on occasions when road and/or rail embankments cause water to pond after torrential rain). Interestingly, var. *pilbarensis* appears to have the capacity to resprout after fire, whereas most other types are killed by fire, even those that cause only minimal canopy scorch. These biological differences have management implications and it it therefore that the the entities be reliably identified.

The large number of Mulga types present in the Pilbara and the complex patterning of these types across the landscape and within communities presents major challenges for biodiversity conservation, land use planning, sustainable agriculture and resource development. At present these challenges are most apparent for the resource development sector where unparalleled demand for iron ore and other Pilbara metals is fostering unprecedented mineral exploration, brown field expansions and green field developments. A precautionary approach, as adopted by government regulators and accepted by most developers, has seen some restrictions placed on operations in relation to Mulga, for example, Hancock railway (Pilbara Iron-PI) and Pilbara Infrastructure Project (Fortescue Metal Group-FMG), a situation that will in all likelihood only become more restrictive as new greenfield areas are opened up and existing disturbance footprints become larger and impact on new Mulga areas. The principal reason why these restrictions currently exist is because questions about the conservation status and impacts of proposed developments on Mulga cannot be confidently answered because of uncertainties concerning the taxonomy of Mulga. Fundamental questions such as the reservation status, distribution and resilience to disturbance of Mulga types cannot be addressed because we cannot distinguish Mulga type A from Type B, from Type C, etc, with any confidence.

...questions about the conservation status and impacts of proposed developments on Mulga cannot be confidently answered because of uncertainties concerning the taxonomy of Mulga.

There have been many studies of the autoecology and ecophysiology of Mulga in the Pilbara over the past 25 years and hence there is a considerable volume of information available on how Mulga functions and responds to disturbance in the region. However, this information is of little value if land management practitioners cannot identify which Mulga types were studied and where these occur in the landscape. To obtain the full benefit from historical, ongoing and future studies of Mulga in the Pilbara, there must have a reliable Mulga taxonomy that can be deployed with confidence. Such a taxonomy would add considerable value to ongoing investigation such as the Fire-Mulga study being undertaken by CALM and the rangeland condition and sustainable agriculture study on Ethel Creek Station by the Mulga Research Centre for BHP Billiton Iron Ore.

Similarly, the planned ecophysiological study of Mulga in the southern Chichester Range by FMG in the offset package for the Pilbara Infrastructure Project (Cloud Break development) and the ecophysiological investigations and rehabilitation trials being undertaken by the Ecosystem Research Group, UWA at West Angelas for Pilbara Iron would benefit from a resolution of Mulga taxonomy.

The restrictions and impediments placed on clearing permits associated with exploration activities, and the impact assessment process associated with brown and green field developments, would be moderated if land managers, developers, biological consultants and government regulators have a better understanding of Mulga taxonomy, distribution and most importantly, its conservation/reservation status, especially of narrow range endemics. This is particular relevant in areas of the central and eastern Hamersley Range (e.g. West Angelas, Angelo River, Rhodes Ridge, Giles, Parmelia Hill, East Angelas, Hope Downs, Wheelarra Hill, Coobinna) and Chichester Range (Christmas Creek, White Knight, Mt Nicholas, Mt Lewin) where there is coincidently exceptional diversity in Mulga types, little opportunity for on-reserve conservation, and significant mineral prospectively.

A better understanding and appreciation of Mulga as would be delivered by this project would have significant benefits to all land management practitioners in the Pilbara and undoubtedly elsewhere across the rangelands of Western Australia. The benefits conferred through increased community capacity in respect to pastoralists, miners, rehabilitation practitioners, biological consultants, government regulators and other land managers and their agents being able to confidently identify the different mulga types, alone justify the project. These benefits for the rangeland community would have significant flow on effects with respect to biodiversity conservation, improvements for sustainable agriculture, enhancements in land rehabilitation and increased certainty for the resource development sector.

Mulga community near Rio Tinto George, Hamersley Range

OBJECTIVES

The overall objective is to elucidate patterns of variation within Mulga in order to provide a reliable means of identifying the numerous entities present. This objective will be achieved by:

- Identifying and sorting known Mulga taxa based on existing herbarium records.
- Locating 'pure' (containing one entity) and 'mixed' (containing more than one entity) populations of different Mulga types across the rangelands.
- Sampling populations to collect material for genetic, anatomical, taxonomic, ontogenetic and possibly embryological study.
- Analysing variation within and between populations using best practice genetic techniques (microsatellites and DNA sequencing), taxonomic methodologies (e.g. critical morphological/anatomical features of pods and phyllodes) and seedling developmental studies.
- Determining factors responsible for creating and maintaining the variation present in Mulga.
- Defining Mulga taxa and providing comprehensive descriptions for all entities.
- Providing an effective means of identifying the Mulga type using interactive electronic keys and the World Wide Web.

DELIVERABLES

This study will deliver a number of outcomes beneficial for land management across the Western Australian rangelands and will have significant flow on benefits for rangeland management across the continent.

The main deliverables will be:

- The most comprehensive taxonomic treatment of Mulga ever undertaken.
- Production of a 'Mulga Manual' (hardcopy and web-based), accessible to the whole community (e.g. resource managers, researchers, educators, regulator, local government administrators, pastoralists, environmentalists etc) describing and illustrating (line drawings and photographs) the different entities within the Mulga group and detailing their variation across the rangelands. The 'Mulga Manual' will also include specific information on plant morphology, biology, ecology, distribution, conservation status and potential utilisation.
- Production of a simplified version of the 'Mulga Manual' targeting non-specialist users such as pastoralists and environmentalists.
- Production of a user-friendly, electronic identification key enabling Mulga types to be easily and reliably identified. This will be made available to the community on CD and via the web.
- Provision of direction for future biological and ecological studies of Mulga so that the species and its congeners may be effectively managed, conserved and sustainably utilized.
- Determination of the genetic factors responsible of causing and maintaining diversity within the Mulga group.
- A significant contribution to genetic research across the rangelands that may assist with the resolution of taxonomic problems in several other important arid zone plant groups.
- Peer-reviewed scientific publications describing new species of Mulga and detailing genetic systems operating within the group.
- Assessment of the conservation status of Mulga taxa in Western Australia.
- A comprehensive basis for understanding Mulga across its entire geographic range within Australia (Mulga are also dominants in areas of the Northern Territory, South Australia, Queensland, New South Wales and Victoria).
- Promotion of the project and its sponsors in CALM's *Landscope* journal and on the web through the *WorldWideWattle* website.

This project will conform to and deliver outcomes that align with numerous Federal and State government initiatives designed to promote sustainable land use and biodiversity conservation across the Australia rangelands. The project will also deliver on several objectives of the recently accredited NRM Strategy for the Western Australian Rangelands.

Acacia aneura var. *intermedia*.

FEDERAL

This project is strategically relevant to the Federal Government's National Heritage Trust 2 initiatives, namely, building community capacity that increases knowledge to promote biodiversity conservation, and sustainable resource use and management of ecosystems. Specifically this project is aligned with the following NHT priorities:

- NHT1 (protect and restore habitat of threatened species and communities).
- NHT2 (reverse native vegetation decline).
- NHT5 (establish and manage CAR reserve system).
- NHT7 (securing sustainable access to natural resources).
- NHT8 (sustainable and profitable management systems).
- NHT9 (enhancing the understanding and skills of landholders, community groups and managers contributing to conservation and sustainable resource development).

The project is consistent with and has strong linkages to the following Federal policies:

- National Strategy for the Conservation of Australia's Biological Diversity.
- National Objectives and Targets for Biodiversity Conservation.
- Directions for the National Reserve System – A Partnership Approach.

Many project deliverables are directly relevant to the activities of several national Co-operative Research Centres, in particular, the Desert Knowledge CRC and Bushfires CRC.

STATE

This project is relevant to addressing a number of the environmental issues and challenges in Western Australian rangelands as defined in the Environmental Protection Authority's Position Statement No. 5 (2004) on "Environmental Protection and Ecological Sustainability of the Rangelands in Western Australia".

As an outcome the project will provide scientific knowledge to assist decision-makers and land-managers. This is a fundamental objective of the State's draft Biodiversity Conservation Strategy, the Biodiversity Audit of Western Australia and State of Environment reporting.

Natural Resource Management

The project addresses the following National Outcomes for NRM as set by the Australian Government:

- Biodiversity and condition of native ecosystems are maintained or rehabilitated.
- Populations of significant species and ecological communities are maintained or rehabilitated.
- Ecosystem services and functions are maintained or rehabilitated.
- The impact of threatening processes on locations and systems which are critical for conservation of biodiversity, agricultural production, towns, infrastructure and cultural and social values, is avoided or minimised.

STRATEGIC NATURE (cont)

- Sustainable production systems are developed and management practices are in place, which maintain or rehabilitate biodiversity and ecosystem services, maintain or enhance resource quality, maintain productive capacity and prevent and manage degradation.

The project will contribute significantly to the fulfilment of numerous Resource Condition Targets (RCTs) and Management Action Targets (MATs) identified in the accredited NRM Strategy for the Western Australia Rangelands. Examples include:

- RCT1 – Community capacity for nature resource management is significantly enhanced by 2025.
- RCT6 – By 2025, maintain or increase vegetation community composition, structure and function in priority areas/landscapes.
- RCT7 – Maintain or improve the conservation status of terrestrial native species and assemblages by 2025.
- MAT-L38 – Undertake native vegetation mapping to improve the scale of mapping from 1:250,000 to 1:100,000, with an initial focus on the current reserve system, by 2010. A relevant specific action is 'to establish consistent method for vegetation mapping'.
- MAT-L41 – Investigate and research the distribution, abundance and ecological requirements of flora and fauna populations for management purposes by 2010. A relevant specific action being to 'Undertake taxonomic studies to resolve problems within ecological important species groups and complexes' and 'Conduct a comprehensive flora and fauna inventory survey/classify species and ecological communities starting in priority areas.'

At the NRM Rangelands subregional level this project will provide outcome relevant to all regions except the Kimberley. For example, in the draft Pilbara subregional plan one of the Biodiversity MATs is to "Undertake taxonomic studies to resolve significant taxonomic problems within ecologically important species groups and complexes, e.g. Mulga".

Acacia aneura var. *microcarpa* (young plant). As this plant matures it will develop an open, obconic growth form. Foliage colour often characterizes different Mulga types.

LINKAGES WITH OTHER ACTIVITIES

The project has direct relevance to a number of research and applied management activities which are currently in progress or planned for the near future within the Western Australia rangelands. Examples include:

- The EMU project which aims to build awareness in the pastoral community in relation to ecological and sustainable land use .
- Mulga autoecological, ecophysiological, and nutrient cycling studies together with mulga rehabilitation trials being undertaken at West Angelas and other central Hamersley Range locations (Ecosystem Research Group, School of Plant Science, University of Western Australia for Pilbara Iron).
- Mulga ecophysiological and water relation study in the Cloud Break and Christmas Creek areas of the Chichester Range (Fortescue Metals Group Environmental Offset program).
- Sustainable land use and range condition studies on Roy Hill Station (Syrinx Environmental for BHP Billiton Iron Ore).
- Rangeland condition and sustainable agriculture studies on Ethel Creek Station (Mulga Research Centre, Curtin University of Technology, for BHP Billiton Iron Ore).
- Pilbara Fire-Mulga Study that is examining issues of Mulga regeneration after fire (CALM with industry-sponsorship through the West Angelas Environmental Offset program, Pilbara Iron).
- Fire management for biodiversity conservation in the northern Goldfield (CALM in collaboration with University of Nebraska, Omaha, USA).
- Mulga and drainage shadow monitoring – Coondewanna West Railway and proposed Hancock Railway (project environmental commitments, Pilbara Iron).

The project has direct relevance to a number of research and applied management activities which are currently in progress or planned for the near future within the Western Australia rangelands.

SUPPORT

The following individuals and groups have research or commercial interests in Mulga and have expressed support for this project:

- Professor J.E.D Fox, Director, Mulga Research Centre, Curtin University of Technology.
- R.D. Flugge, Vice-chair, Rangeland NRM Co-ordinating Group.
- Dr P. Grierson, Leader, Ecosystem Research Group, School of Plant Science University of Western Australia,
- Dr P. Landman, Manager, Environment and Government Relations, Pilbara Iron.
- M.E. Trudgen, Director, Trudgen & Associates, Perth.
- D. & D. O'Meara, Directors, Outback Trees of Australia & De Grey Mining, Perth.
- K.J. Walker, Principal, KJ Environmental, Newman.
- M. Maier, Principal, Biota Environmental Sciences, Perth.
- T. & R. Richardson, Lessees, Mt Florence Station.

METHODS

Acacia aneura var. *fuliginea*. The colour of the new shoots can be helpful in identifying Mulga types. In this variety (and some others) the new shoots are covered by a dense layer of chocolate brown resin hairs.

The Mulga group is a large and very complex assemblage of species. Conventional taxonomic methodology alone is unlikely to resolve this variation. This is why a multi-disciplinary, collaborative approach has been adopted. The following strategies will be adopted.

PARTICIPANTS

1. B.R. Maslin, Department of Conservation and Land Management, Perth, Western Australia. (Taxonomy.)
2. Dr J.T. Miller, Department of Biological Sciences, The University of Iowa, U.S.A. (Genetics.)
3. Dr M. Byrne, Department of Conservation and Land Management, Perth, Western Australia. (Genetics.)
4. Dr R. Rutishauser, Institute of Systematic Botany, University of Zurich, Switzerland. (Anatomy.)

TARGET AREA

The primary target areas for intensive study will be Pilbara region and the northeastern goldfields region (roughly Menzies-Wiluna-Meekatharra-Mount Magnet area). These areas represent the main centres of diversity for Mulga in Western Australia and most of the known Mulga types occur within this zone. However, relevant taxa that occur outside these areas will be included in the analyses in order to provide taxonomic context.

FIELD STUDY

1. Locate and intensively sample plants from monotypic stands of the different forms of Mulga (i.e. populations containing only a single taxonomic entity). This is necessary to "genetically type" the entities. The currently described 22 taxa that comprise the Mulga group are listed in Appendix 1 and the study will primarily focus on those in the 'core group' of species. It is expected, however, that as a result of this project a number of as-yet undescribed species will be described.

2. Locate and intensively sample plants from at least five mixed stands of Mulga (i.e. populations containing different taxonomic entities). Current experience shows these to be the most common type of Mulga populations found in nature; more than 10 different forms can co-exist within a single stand. This approach is necessary to genetically 'fingerprint' the forms and to correlate these forms with described and named entities.

3. Sample plants judiciously selected from across the range of Mulga within the target area (to locate taxonomic entities not encompassed by the intensive study sites noted above). This will allow the genetic comparison of similar-looking plants from different areas to determine if they also similar genetically. This is necessary to ensure that the identification tools we construct to identify different forms of Mulga work effectively.

4. The selection of the above sites will be determined by examination of the existing extensive Mulga collections at the Western Australian Herbarium (about 1 500 specimens), by analysis of results from fingerprinting of already-collected material (see #2 below) and by field survey.

5. Material collected from the field surveys will be used in genetic, taxonomic, ontogenetic and anatomical studies.

The Mulga group is a large and very complex assemblage of species. Conventional taxonomic methodology alone is unlikely to resolve this variation.

GENETIC STUDY

1. Microsatellite genetic markers will be developed to DNA fingerprint Mulga. This process requires the construction of a DNA library, DNA sequencing, creation and testing of the markers. Byrne has initiated this work already, and is in the process of creating and testing the fingerprinting markers.

2. Fingerprinting already-collected material to test genetic markers and to guide selection of field study sites. Miller will utilize the markers created by Byrne to test 200 samples previously collected.

3. Fingerprint newly collected material. Individual projects will determine genetic relationships within individual mixed Mulga populations. These data will be compared to data from monotypic stands and selected collections across populations to develop broader taxonomic hypotheses.

Acacia aneura var. *pilbarana* on floodplain of Fortescue River. This variety is confined to the Pilbara and Ashburton districts.

TAXONOMIC ANALYSIS

1. Identify and discriminate the different biological entities comprising the Mulga group.

2. Measure phyllode, pod and seed characteristics, such as size and shape, of previously collected and newly collected material. Morphological data will be analysed using Principal Components Analyses and will be correlated with the genetic data.

3. Formally describe the Mulga entities (species, subspecies, varieties, etc), including new species.

4. Provide a reliable means of identifying the Mulga entities (using the electronic interactive identification program, Lucid). In a group as complex as Mulga and where the differences between the taxa are so variable and often very subtle, the only reliable means of identification is through the use of an electronic interactive key. Such a key will accompany the 'Mulga Manual' and will also be make available via the WorldWideWattle website. The Manual will also provide hardcopy identification aids, along with colour photographs of the taxa, distribution maps, descriptions, utilisation facts, etc.

COMPLEMENTARY STUDIES

1. Anatomical investigation of pod and phyllodes venation patterns (by Rutishauser) is necessary so that these characters may be effectively used in the taxonomic analysis. Of particular relevance is the need to develop a proper understanding of the so-called 'wing' of the pods that has hitherto been critically important in the identification of the taxa. Also, phyllode venation pattern analyses will aid in the study of hybridity between certain species, especially hybrids involving *A. craspedocarpa*.

2. Ontogenetic information derived from seedling leaf development will similarly help in the identification and classification of Mulga taxa. Current evidence shows that neoteny (i.e. retention of juvenile features in adult growth phase) occurs in at least some Mulga species (see Miller *et al*. 2002) and this phenomenon may be responsible for contributing to at least some of the intra-population complexities observed in nature.

3. We have indirect evidence of apomixes (asexual seed production) and polyploidy (multiple sets of chromosomes) in Mulga. We hypothesize that these are important factors in the creation and maintenance of the extensive morphological variation within the group. Using previously collected and new material Miller will develop protocols to document these events.

OPERATIONAL DETAILS

Preparatory to the field study the extensive collections of Mulga housed at the Western Australian Herbarium will need to be examined and sorted. This will not only help in the selection of field sites for sampling for genetic and other investigations, but will enable a taxonomic framework to be developed for the whole study. This framework will involve applying names to species using the most recent revision of Mulga (Pedley 2001), applying informal names to entities that are not accounted for by Pedley, and developing a provisional electronic key to identify the taxa.

Extensive fieldwork will be conducted throughout the target area in 2006-07, 2007-08 and 2008-09. The objective of this work will be to locate pure and mixed populations of the different Mulga entities from which material for genetic, taxonomic and ontogenetic studies will be collected. The field work will also enable us to become familiar with the biology, ecology and population dynamics of Mulga species.

It is anticipated that the following sampling strategy will be adopted:

1. Fifty to sixty pure (monotypic) populations of Mulga, representing about 22 taxa, will be sampled. Material for genetic and other analyses will be taken from 15 plants within each population.

2. Five to seven mixed populations of Mulga, each containing up to about 10 different entities, will be sampled. Material for genetic and other analyses will be taken from about 200 plants within each population.

Voucher specimens representing all populations and taxa sampled will be collected and deposited at the Western Australian Herbarium.

Maslin will co-ordinate the field program which will be timed, insofar as possible, to coincide with flowering and (particularly) fruiting of the plants. Mulga like may other arid zone plants, flowers and fruits in response to rainfall, and given the rainfall received to date, 2006 should be a bountiful for Mulga flowering and fruiting. If there is little or no rainfall in a particular year this will constrain (but not stop) the field program. Rainfall in the arid zone is usually patchy, but given the large geographical area covered by this study it is expected that at some flowering/fruiting populations of each entity will be able to be located in each year of the project.

Acacia aneura var. *conifer*. Although this Mulga type has a distinctive growth form its taxonomic status needs reviewing.

Maslin and Miller have already conducted field studies of Western Australian rangeland (and Northern Territory) Mulga populations and their publication (Miller *et al.* 2001) outlines the conceptual basis of the present investigation. Miller will participate in the field program each year and this will provide the opportunity to plan future activities, discuss results and to prepare publications. Rutishauser will join the field program in the second year of the project.

The microsatellite analyses will be undertaken by Byrne (in Perth) and the DNA sequencing by Miller (in Iowa) who will also conduct microsatellite analyses on around 650 samples of Mulga that has already been collected. The anatomical investigations will be conducted by Rutishauser in Zurich and the taxonomic work by Maslin in Perth.

Regular reporting will occur and relevant information will be widely disseminated throughout the project via the WorldWideWattle website.

This project is being undertaken by a team of specialists who have extensive experience and publication records in their respective fields. They also have a proven track-record of delivering outcomes on time and to specification. The project is timely, well-conceived, well-designed, technically feasible and will provide information and outputs that meet its objectives.

MONITORING, EVALUATING AND REPORTING

- Completion of major milestones will be reported through CALM's science review process. Presentations on progress will be provided as required by the funding sponsors.
- Regular updates on the status of the project will be provided on CALM's Worldwidewattle website.
- Article on Mulga will be published in CALM's *Landscope* magazine during the first year of the project.
- Interim advice concerning the taxonomic status of Mulga in the W.A. rangelands will be provided as requested.
- Analysis of results will be completed in 2008/09 and the ensuing genetic and taxonomic papers will subsequently be published in refereed scientific journals. The 'Mulga Manual' (containing the descriptive, biological, geographic and other data for each Mulga entity), the simplified version of the Manual, together with the interactive identification key, will be completed in this same period; these will be made available as both paper-based and web-based documents.

RISK MANAGEMENT

Specific Risk	Description of Risk	Likelihood and impact	Strategies to manage identified risks
Genetic analysis	Gene markers not viable for some taxa or do not distinguish between taxa.	Low (based on preliminary analysis by Andrew *et al.* (2003)	Two different markers are being used.
Pods not produced	Identification of some Mulga taxa is dependent upon collections of pods (& pod production depends upon rainfall which is patchy and unreliable in	rangelands). Failure to produce pods is likely in some populations, but impact should be low. Extensive field survey designed to maximize chance of	locating pod-producing populations. Existing collections will provide back-up material.
Some Mulga taxa not amenable to conventional taxonomic methodology	Depending upon the nature and extent of the genetic variation, it may not be possible to define and key ever Mulga taxon reliably.	Current evidence suggests that few entities may not be amenable to conventional taxonomy.	The use of electronic interactive keys greatly facilitates identification and are likely to minimize the impact of this potential risk.

Acacia aneura var. *intermedia*. The shape, size and colour of phyllodes and whether or not the pods possess a narrow marginal 'wing' (as does this variety) are important characters for distinguishing the types.

PROJECT SCHEDULE

The proposed schedule (thus budget) for this 3 year study recognizes the high numbers and variability of Mulga taxa, and the extensive geographic range they occupy and the labour-intensive nature of the research to be undertaken. It also allows for vagaries of flower/fruit production in Mulga (which is rainfall-dependent). A detailed work schedule for Year 1 is provided below, followed by an outline of schedules for Years 2 and 3 (details of work to be conducted in the second and third year will be dependent upon outcomes from Year 1).

YEAR 1

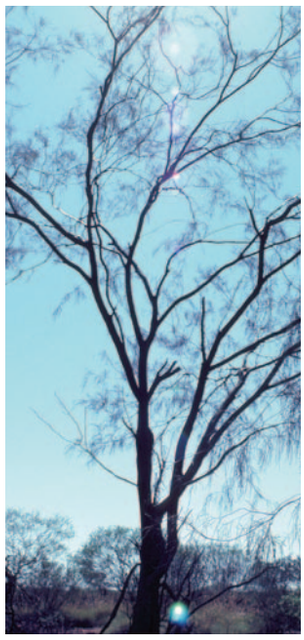
Note: This schedule assumes that the project will commence in July 2006 so that we can take advantage of this year's anticipated favourable fruiting following good rainfall in the rangelands.

Activity	Actions	Duration	Performance indicator
Herbarium study	Preliminary sort of Herbarium material. (Maslin)	6 weeks	Herbarium material sorted & field sampling sites identified.
Field survey	Locate & sample 'pure' and 'mixed' populations (April/May 2006–flowers; Sept./Oct. 2006–pods; 2007-timing dependent on rainfall). (Maslin & Miller)	10 weeks	Populations located and sampled for flowers and fruits.
Collection processing	Process 2006-07 field collections. (Maslin)	8 weeks	Specimens processed, named & incorporated into Herbarium; material to Rutishauser for anatomy study.
Morphological analyses of collections	a) 2001 collections (Miller) b) 2006-07 collections & existing herbarium material (Maslin)	a) 4 weeks b) 24 weeks	Morphological characters from a) & b) measured; herbarium material scrutinized.
Microsatellite library	Develop DNA microsatellite) library. (Byrne)	2 weeks	Microsatellite library completed.
DNA extractions	Extract DNA from material collected 2006-07 & make available for genetic analysis. (Byrne)	6 weeks	DNA extracted & distributed for genetic study.
Genetic fingerprinting	a) Using microsatellites of 2006-07 material. (Byrne) b) Using DNA sequencing of 2006-07 material. (Miller) c) Using microsatellites of 2001 material (Miller)	a) 12 weeks b) 12 weeks c) 8 weeks	Genetic fingerprinting of collections completed.
Ontogenetic study	Establish & monitor seedling trials. (Maslin)	6 weeks	Seedling trials from 2006-07 collections established; destructively sampled and measured.
Publicity	a) Construct and maintain *Worldwidewattle* web site detailing project. (Maslin) b) Prepare article on Mulga for *Landscope*. (Maslin)	4 weeks	a) *Worldwidewattle* content describes project and acknowledges sponsors; site maintained. b) *Landscope* article published.

YEAR 2

Based on the results derived from Year 1 studies:

1. Undertake field work to locate and sample 'pure' and 'mixed' populations of Mulga. (Maslin, Miller & Rutishauser)
2. Process field collections and distribute material to participants for specialist study. (Maslin)
3. Progress morphological examination of morphological attributes of specimens collected, plus those at the W.A. Herbarium. (Maslin)
4. Continue genetic fingerprinting using microsatellites and DNA sequencing. (Miller & Byrne)
5. Continue anatomical study. (Rutishauser)
6. Progress ontogenetic study. (Maslin)
7. Refer taxa to CALM's Declared Rare Flora and Priority Flora Lists where appropriate. (Maslin)
8. Maintain the WorldWideWattle website for Mulga. (Maslin)



Weeping Mulga (*A. paraneura*). Another distinctive Mulga type with its normally drooping branchlets and phyllodes.

YEAR 3

Based on the results derived from Years 1&2 studies:

1. Undertake field work on an 'as needed' basis to fill in gaps in knowledge. (Maslin & Miller)
2. Process field collections and distribute material to participants for specialist study. (Maslin)
3. Complete morphological examination of attributes and analyse results using Principal Components Analysis (correlating with genetic and complementary study results). (Maslin)
4. Complete genetic fingerprinting using microsatellites and DNA sequencing. (Miller & Byrne)
5. Complete anatomical and ontogenetic studies. (Rutishauser & Maslin)
6. Refer taxa to CALM's Declared Rare Flora and Priority Flora Lists where appropriate. (Maslin)
7. Maintain the WorldWideWattle website for Mulga. (Maslin)
8. Prepare 'Mulga Manual', the simplified version of the Manual, and the electronic identification key for publication. (Maslin)
9. Publish in appropriate scientific journals the results of the study, including descriptions of new species. (Maslin, Miller, Byrne & Rutishauser)

FINANCIAL DETAILS

TOTAL BUDGET AND FUNDING SOURCES

The following table shows the total cost of the project, with funding sources identified.

Major Activity	Budget Total ($)	Source of Funding				
		CALM		University of Iowa		Sponsorship Sought
		In kind[1]	Cash	In kind[1]	Cash	
Taxonomy	339 397	243 168	10 000			86 229
Genetics	119 460	26 295		24 000	4 000	65 165
Field work	38 160	7 206				30 954
Travel	3 250					3 250
Materials (See Budget (Year 1) below for detail)	10 000					10 000
Total (Year 1)	510 267	276 669	10 000	24 000	4 000	195 598
Total (Year 2)[2]	499 324	276 669	10 000	24 000	4 000	184 655
Total (Year 3)[2]	506 413	276 669	10 000	24 000	4 000	191 744
Total (Years 1–3)	1 516 004	830 007	30 000	72 000	12 000	571 997

1 Includes Departmental personnel and overheads (including genetics laboratory).

2 Salary costs for years 2 & 3 include a 5% annual increase to cover anticipated pay increases; 5% annual increase in vehicle running costs (fuel) has also been incorporated into Fieldwork costs. The field and laboratory components in year 3 of the project will be reduced in anticipation of the need for time to write-up results. However, in the third year there will be the cost of publishing the Mulga Manual and the simplified version of this (together estimated at $30 000).

BUDGET SOUGHT THROUGH SPONSORSHIP (YEAR 1)

Major Activity	Budget ($)	Justification
Taxonomic investigation (Maslin)		See Note 1.
a) Research assistant	79 229	
b) Herbarium costs	7 000	
Genetic investigation (Byrne & Miller)		See Note 2.
a) Employment	43 265	
b) Consumables etc.	21 900	
Field work		See Note 3.
a) Vehicle	15 954	
b) Accommodation	15 000	
Materials	10 000	See Note 4.
Travel	3 250	See Note 5.
Total	195 598	

BUDGET (YEAR 1) EXPLANATION AND JUSTIFICATION

The above costs reflect the fact that this is a scientifically and logistically a very challenging project. Mulga is a large, complex group of plants with a wide geographic spread within the rangelands. The complex patterns of variation require specialist techniques to elucidate; this is a task that has eluded researchers to date.

Note 1. Taxonomic investigation necessitates employment of a Research Assistant to assist Maslin, plus Herbarium bench fees ($2 000 p.a.), specimen processing costs (calculated at 200 specimens p.a. @ $25/specimen), glasshouse supplies and computer. It is expected that around 22 different taxa of Mulga (plus numerous hybrids) will be encountered that will require sampling and analysis. A Level 5 Research Assistant is the minimum required to enable the appointment of someone with the appropriate skills to facilitate this taxonomically complex project. The $79 229 (employment cost) includes Departmental overheads. 5% p.a. has been built in to the salary for years 2 & 3 of the project to cover anticipated wage increases.

Note 2. The success of this project is contingent upon having access to genetic information, the costs of which are identified under this heading. These costs include the employment of specialists skilled in the two genetic techniques that will be used (microsatellites and DNA sequencing), respective Departmental overheads and consumables. The costs are based on the realistic expectation that around 1660 samples from 'pure' and 'mixed' populations will be examined genetically, along with around 300 samples that were collected from the WA rangelands in 2001.

Note 3. Apart form sampling for taxonomic and genetic studies the field work is an essential component of the project in order to develop an understanding of population dynamics, variation patterns, ontogenetic sequences, etc. The cost of field work includes vehicle running costs and accommodation (camping and some hotel , for 3 or 4 people). The areas to be sampled involve large distances and around 7-8 weeks will be spent in the field.

Note 4. Materials include computer (for Research Assistant), car and laboratory fridge (needed to store genetic material collected), GPS unit, and glasshouse supplies (for ontogenetic study).

Note 5. The travel costs are for Miller (1 trip) to WA from the USA (airfares and accommodation in Perth; field costs are covered under item 3 above). Miller's involvement is especially crucial to assist Maslin in selecting the sampling sites and to discuss genetic methodology and results with Byrne.

Acacia aneura var. *major*.

REFERENCES

Andrew, R., Miller, J.T., Peakall, R., Crisp, M.D. and Bayer, R.J. (2003). Genetic, cytogenetic and morphological patterns in a mixed mulga population: evidence for apomixis. *Australian Systematic Botany* 16(1): 69-80.

Beale, I.F. (1994). Management of Mulga (Acacia aneura) Scrublands in Southwest Queensland. In 'Forage Tree Legumes in Tropical Agriculture'. (Eds RC Gutteridge and HM Shelton) pp. 325-337. (CAB International)

Everist, S.L. (1949). Mulga (*Acacia aneura* F.Muell.) in Queensland. *Queensland Journal of Agricultural Science* 6: 87–131.

Fox, J.E.D (1976, unpublished report). The silviculture of Acacia aneura (mulga): growth, regeneration and stability in relation to cutting, grazing and fire. (Western Australian Institute of Technology: Perth.)

Fox, J.E.D.(1977, unpublished). 'Natural regeneration and growth of mulga (Acacia aneura F. Muell ex Benth.) in Western Australia.' Western Australian Institute of Technology. (Submission to Australian Research Grants Committee.)

Maslin, B.R. (2002).. The role and relevance of taxonomy in the conservation and utilisation of Australian Acacias. Conservation Science Western Australia 4(3): 1-9.

Midgley, S.J. and Gunn, B.V. (1985). *Acacia aneura* seed collections for international provenance trials. *Forest Genetic Resources Information* 13: 21–29. (FAO: Rome.)

Miller, J.T., Andrew, R.A. and Maslin, B.R. (2002). Towards an understanding of variation in the Mulga complex (*Acacia aneura* and relatives). *Conservation Science Western Australia* 4: 19-35. This paper is available on the internet at http://science.calm.wa.gov.au/cswajournal/4-3/19-35.pdf.

Miller, S.M. (1994). The role of Acacia aneura in Animal Production. In 'Forage Tree Legumes in Tropical Agriculture'. (Eds RC Gutteridge and HM Shelton) pp. 245-254. (CAB International)

Pedley, L. (2001). *Acacia aneura* and relatives. *Flora of Australia* 11B, *Mimosaceae, Acacia part 1* (A.E.Orchard and A.J.G.Wilson, eds), pp. 309–328. (Australian Biological Resources Study, Canberra, and CSIRO Publishing, Melbourne.)

Randell, B.R. (1992). Mulga, a revision of the major species. *Journal of the Adelaide Botanic Garden* 14: 105–132.

Start, A.N. (1986). Status and management of Mulga in the Pilbara region of Western Australia. pp. 136-138 in P.S. Sattler (ed) *The Mulga Lands*. (Royal Society of Queensland: Brisbane.)

van Leeuwen, S.J., Start, A.N., Bromilow, R.N. and Fuller, P.J. (1995). Fire and the floristics of mulga woodlands in the Hamersley Ranges, Western Australia. pp.169-175. In: M.J. Page and T.S. Beutel (eds) *Ecological Research and Management in the Mulga lands* - Conference Proceedings. (University of Queensland Gatton College: Brisbane).

Williams, J. (2002). Fire regimes and their impacts in the mulga (Acacia aneura) landscapes of central Australia. Environment of Australia website: www.deh.gov.au/soe/techpapers/fire/part3/pubs/part3.pdf.

Acacia aneura var. *tunuis*. This Mulga has slender phyllodes as its botanical name implies.