E1: Project Title: Beyond discrete landscape metrics: spatial analysis tools and surface textural measures for quantifying gradients in landscape structure.

E2: Project Description and Background:

Aim: The project will develop conceptual models, surface textural measures, spatial analysis techniques and a computer-based spatial analysis package for quantifying gradients in landscape structure. It addresses important gaps in the knowledge and application of landscape ecological studies, from both a theoretical and applied perspective: (i) failure to conceptualise and quantify continuous gradients in landscape structure; and hence (ii) inability of many studies to test the ecological importance of landscape gradients for fauna conservation in Australia's terrestrial, marine and aquatic environments. The project brings together emerging theories and tools in remote sensing and spatial analysis, and links these with the gradient concept of landscape structure. The challenge, then, is to test if the continuous landscape context is important for fauna populations, and if so, what landscape attributes and surface textural measures are most suitable for quantifying fauna-landscape relationships. By filling this gap, the project outcomes will advance landscape ecological research, in Australia and internationally and thereby deliver important benefits for the fauna conservation and sustainable landscape management.

The specific objectives of the project are:

1. Develop a conceptual framework based on scale for linking spatial gradients in landscape structure with species occurrence and abundance.
2. Identify and evaluate suitable continuous, non-discrete landscape metrics/surface measures and analysis techniques for quantifying gradients in landscape structure.
3. Empirically test the ecological relevance and interpretability of suitable continuous metrics and spatial analysis techniques as indicators of fauna distribution and abundance for two terrestrial case study areas in sub-tropical and tropical Australia.
4. Develop a computer-based toolbox of ecologically meaningful landscape metrics and spatial analysis techniques, plus supporting documentation, suitable for quantifying and explaining gradients in landscape structure.

Background: The recent progress in terrestrial, and more recently marine, landscape ecology has been based on the discrete boundary model of landscape structure (Forman 1995; Wiens 1995; Turner *et al.* 2001; Pittman *et al.* 2004). In Australia, landscape ecology has made considerable progress in recent decades in understanding how the structure of human-modified landscapes influences the occurrence and viability of fauna populations and sustainable landscape function (e.g., Ludwig *et al.* 1996; Laurance 1997; Ford *et al.* 2001; Lindenmayer *et al.* 2002). However, many of the current concepts (Forman 1995) and quantitative techniques (e.g., FRAGSTATS, McGarigal and Ene 2003) of landscape ecology are based on the concept of a mosaic of discrete habitat patches derived from categorical maps. This model has its origins in cartography and choropleth mapping, and assumes that habitat boundaries are inherently discrete with the researcher having to decide how to define habitat classes and map patch boundaries from an organism or process perspective (Pearson *et al.* 1996). This can be a subjective process, with the decision on what to map and how to define patch boundaries determining what patterns will be captured and, hence, what relationships are inferred. The discrete model also fails to accurately capture the internal heterogeneity both within patches and among patches, with all locations in the same class assumed homogeneous in a single or composite attribute. Further, information is lost between map layers in terms of the covariation of environmental factors such as soil, topography and vegetation.

However, in intact landscapes, environmental variability is often continuous rather than categorical (Table 1), with organisms and ecological processes responding continuously at a range of spatial scales to this variability (Austin 1995). Humans modify these primary gradients in vegetation structure (resulting from the interaction of vegetation, soil, water, light and temperature) through disturbance processes such as clearing, thinning, trampling, resource extraction, grazing and fire. Sharp well defined boundaries between human land use and vegetation cover exist where human modification is intensive and spatially discrete, for example in urban or agricultural landscapes (Table 1). Where modification is less intensive and spatially variable, a variegated pattern of both well-defined edges superimposed on continuous gradients in vegetation structure exists (McIntyre 1994). The critical feature in intact and variegated landscapes is that structural variation (natural and disturbance) occurs over a continuous range of scales, with modifications to the natural vegetation cover frequently expressed as gradients rather than discrete boundaries. Equally important, the matrix still consists of native vegetation in various states of modification resulting from spatially variable rates of human-induced disturbance (McIntyre 1994). Simple landscape metrics such as the area of a particular habitat type or patch size fail to adequately capture these gradients in the partially-modified variegated structure. Rather, the landscape is best represented by a continuous surface or several surfaces corresponding to spatially correlated environmental attributes such as topography, soil and vegetation. While the discrete patch mosaic model is still realistic in fragmented and relictual landscapes, a gradient or continuous approach allows for a more realistic representation of landscape heterogeneity in variegated and intact landscapes by not imposing discrete classes and boundaries. The challenge for ecologists is to test if the landscape context is important in variegated and intact landscapes, and if so, what spatial measures of landscape structure are most relevant to fauna populations.

Table 1: Four states of landscape alteration defined by the degree of habitat destruction (Source: McIntyre and Hobbs 1999).

Type of alteration	Degree of destruction of habitat (% remaining)	Connectivity of remaining habitat	Degree of modification of remaining habitat	Pattern of modification of remaining habitat
Intact	little or none (>90)	High	generally low	mosaic with gradients
Variegated	moderate (60-90)	generally high, but lower for species sensitive to habitat modification	low to high	mosaic that may have both gradients and abrupt boundaries
Fragmented	high (10-60)	generally low, but varies with mobility of species and arrangement on landscape	low to high	gradients with fragments less evident
Relictual	extreme (<10)	None	generally highly modified	generally uniform

Landscape pattern analysis programs such as FRAGSTATS, which rely on categorical maps defined by the user, have facilitated rapid advances in quantitative landscape ecology over the past decade. However, recent experience landscape-level studies in terrestrial and marine landscapes in sub-tropical Australia (kangaroos in South Australia's sheep rangelands, Pople *et al.* in review; gliders and birds in continuous forest landscapes, McAlpine and Eyre 2002; koalas in fragmented coastal landscapes, McAlpine *et al.* in review; coastal seagrass landscapes, Pittman *et al.* 2004), have identified the need for an expanded toolbox of landscape metrics which capture both discrete and continuous variations in landscape structure. Kevin McGarigal, the developer of FRAGSTATS, in a keynote address to the International Association of Landscape Ecology World Congress in

Darwin in 2003, predicted the expansion of discrete patch mosaic metrics to include a gradient-based concept of landscape structure, with the discrete patch-mosaic model remaining relevant to fragmented and relictual landscapes. Li and Wu (2004), in a recent review the use of landscape indices, suggest three main misuses of landscape metrics: (1) conceptual flaws in landscape pattern analysis; (2) inherent limitations of landscape indices; and (3) improper use of landscape indices. They suggest that such misuses can arise from a lack of consideration of the relationship between patterns and process, or conversely the assumption of a relationship between a particular process and pattern that has not been quantified and incorrect use of scale. While the authors were specifically referring to discrete landscape metrics, the issues raised are equally if not more relevant to the application of largely untested non-discrete or continuous metrics. Without adequate testing of their ecological relevance and inherent limitations, the accuracy and reliability of a new generation of metrics will be uncertain.

Alternative landscape analysis tools for quantifying gradients in landscape structure are emerging as an important research area in international landscape ecology. This challenge requires exploring appropriate spatial analysis techniques that describe non-discrete metrics for continuously varying variables which exhibit spatial dependence over surfaces, and then test their ecological significance for fauna species and ecological processes in real world landscapes. Modern active and passive remote sensing technologies provide landscape ecologists with a cost effective and repeatable multi-resolution data sources for quantifying gradients in landscape heterogeneity at multiple-scales, and detecting scale-specific spatial and temporal patterns of heterogeneity (Griffiths and Mather 2000; Hay *et al.* 2001). Remote sensing, applied in conjunction with geographic information systems (GIS) and modern geostatistical and spatial analysis methods, provides the tools for quantifying and analysing gradients in landscape structure over both small and large areas.

E3: Significance and Innovation.

The project is at the cutting edge of international and Australian landscape ecological research, explicitly dealing with the problem of continuous structural variation that is characteristic of variegated and intact landscapes in terrestrial, aquatic and marine environments. This problem will be addressed by applying surface textural measures and spatial analysis techniques at scales relevant to the movement of target fauna species. The techniques will draw on related fields of remote sensing and spatial analysis, plus techniques such as surface metrology developed in microscopy and molecular physics for analysing three-dimensional surfaces. For the first time, landscape analysis tools designed for quantifying landscapes gradients will be readily available to ecologists and conservation mangers working in intact and variegated landscapes. The initial conceptual and development focus will be on terrestrial landscapes although we envisage the tools and techniques also will be applicable to marine environments such as in-shore seagrass habitats, and aquatic environments such as wetlands. In these environments, there is the urgent need to develop a systematic, quantitative approach that embraces the structural and functional complexity of landscape gradients. Such an approach would represent a major advance on the current inappropriate concepts and quantitative techniques based on discrete patches of varying habitat quality (Forman and Godron 1986; Forman 1995). Discrete landscape metrics derived from categorical maps force gradients in landscape structure into homogeneous patches with imprecise boundaries and class divisions. However, more appropriate landscape analysis techniques, which deal with the problem of smooth, continuous variation, are needed to provide ecologically meaningful information for biodiversity conservation and sustainable landscape management in intact and variegated landscapes.

The project will build on recent advances by (Ludwig *et al.* 1997, 2005) in the development of new landscape metrics that aim to indicate the 'leakiness' of landscapes, that is, how the structure and configuration of vegetation in a landscape function to retain, not leak, resources such as soils. This work has pioneered the development of landscape leakiness indicators or metrics that can be calculated from remotely-sensed satellite data so that these indicators will function as monitoring tools of sustainable landscape function. The proposed project will evaluate and test the ecological relevance for fauna populations of landscape leakiness indicators, plus a range of largely untested non-discrete landscape metrics, which quantify the intensity (height), slope and curvature of gradients in landscape structure where the habitat quality at each location is represented by the height of the surface. Each landscape will be represented as a continuous surface or as several surfaces corresponding to different environmental attributes (e.g., elevation, topographic wetness).

The project will use state-of-the-art remote sensing technologies to capture fine-scale gradients in landscape structure at spatial resolutions as fine as 2-4 m, thereby extending the ecological application of high-spatial resolution remote sensing technologies in Australia. At present, these investments have a forest inventory and carbon accounting focus. While they are addressing important environmental management issues, there is an ideal opportunity to extend their application to important ecological applications such as sustainable landscape management and biodiversity conservation.

The final output of the project will be a user-friendly computer software package containing landscape analysis tools, spatial statistics and surface textural metrics capable of quantifying gradients in landscape structure at spatial scales (grain and extent) defined by the user. The package will be accompanied by a comprehensive manual of how to use the software, the ecological interpretation of each surface metric, its mathematical derivation plus a statement of inherent limitations. Together, the software and supporting documentation will equip Australian and international landscape ecologists, conservation biologists, wildlife ecologists, plus marine and aquatic ecologists to ask and answer new research questions about the influence of landscape gradients on species occurrence, abundance and persistence.

E4: Approach.

The project will be broken into four key components:

Component 1: Conceptual framework.
This component will address Objective 1, and will develop a conceptual framework of how to represent habitat gradients at the landscape-level (100s – 1000s ha), and the functional response of fauna to these gradients. The conceptual framework behind discrete landscape indices is to describe areal, lineal and topological metrics for landscape patterns (Haines-Young and Chopping, 1996). From a species perspective, both variegated and intact landscapes are a continuous surface of habitat resources of varying quality. The patterns in a landscape surface of interest to landscape ecologists are emergent properties of particular combinations of surface intensity or height and slope across the landscape. The intensity is represented by habitat quality measures such tree density, leaf area index, vertical structural complexity, woody and herbaceous biomass, and seagrass density (Figure 1). Locations with a high habitat quality have a high intensity and height value, while low quality habitats have a correspondingly low value. The slope and curvature of the gradient provides the horizontal dimension, with the steepness and curvature of the gradient reflecting spatial variation in habitat quality. Functionally, these gradients differentially act as a scale-dependent “filter” on the movement of species with different degrees of mobility. This filtering effect varies with the scale and direction of species movement, with less mobile species more strongly influenced by habitat quality at the scale of the home range, compared to more mobile species, which integrate gradients in landscape structure at larger spatial extents (Rhodes *et al.* in review; Figure 1). In relatively continuous landscapes, where habitat quality varies smoothly, it is likely that the filtering effect of landscape structure will be smooth, reducing the rate of movement of some species while enhancing that of others, depending on their size, mobility and habitat requirements (Keitt *et al.* 1997). In more heterogeneous landscapes, the peak and valley zones will differentially filter species movement. Further, the filtering effect may be directional,

with some landscape features such as riparian zones acting as conduits to species movement while others such as treeless savannas acting as barriers. We also recognise that the seasonal dynamics of habitat quality is important in many landscapes (e.g. tropical savannas, wetlands). However, our initial research focus is on quantifying and testing spatial gradients in landscape structure, with seasonal variation in habitat quality represented by multiple spatial gradients of varying intensity and slope. The challenge is to then link species distribution and abundance with these dynamic landscape gradients using continuous landscape metrics at spatial resolutions and extents relevant to the ecology and movement of the target species. This will be guided by ecological knowledge of target fauna species to test how well continuous landscape metrics match observed patterns in species distribution and abundance.

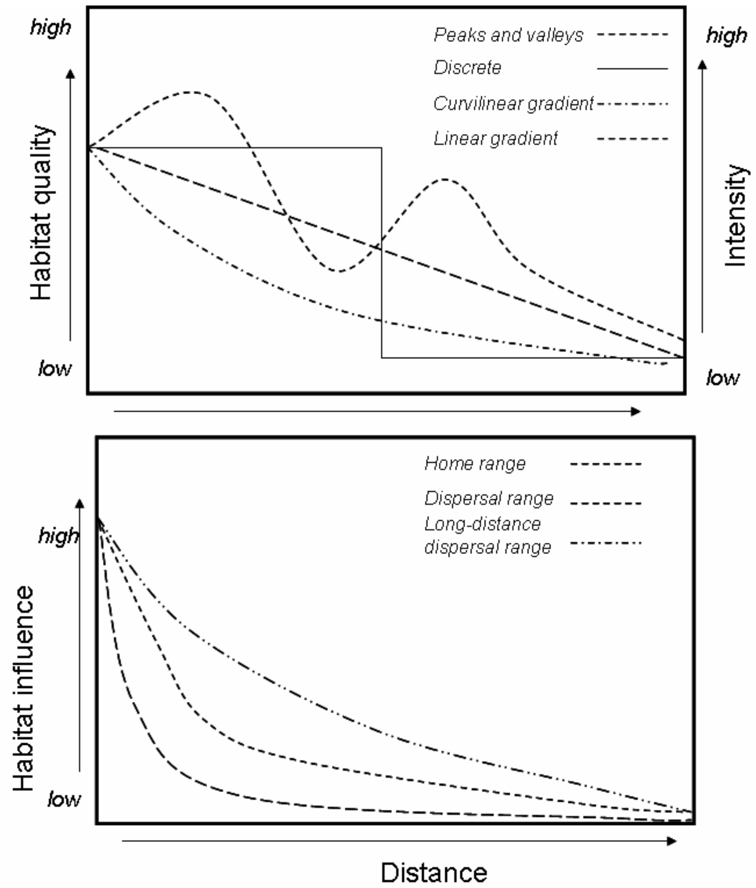

Figure 1: Two-dimensional conceptual model of landscape gradients in habitat quality of different intensity, slope and curvature, and differences in the filtering effect of these gradients according to the scale of movement of different species. In three-dimensional landscapes, gradients may take different forms in different directions, with a resulting directional filtering effect on species movement. For example, linear riparian landscapes in savanna environments may have a low filtering effect on the movement of some bird species, while the more open savanna landscapes act as a stronger filter to species movement.

Output: Conceptual model of how three-dimensional landscape gradients influence fauna populations with varying habitat preferences and scales of movement.

Component 2: Critical review and evaluate landscape surface measures and spatial analysis techniques.

This component relates to Objective 2, and involves a critical review and evaluation of a set of surface textural measures and spatial analysis techniques that can be used for quantifying species-landscape relationships in landscapes with a continuous structure (see Component 1). We will bring together emerging theories and tools in image processing and spatial analysis in order to evaluate their suitability for quantifying three-dimensional spatial and temporal gradients in landscape structure. The overall objective is to characterise landscapes in terms of continuous or gradient-based spatial measures (e.g., surfaces of varying intensity and slope, spatial neighbourhoods, spatial autocorrelation). In some cases, there variables have straightforward analogous descriptions to landscape categorical variables such as shape, clumping, proportion, but have the additional benefit of being defined continuously and for multiple spatial scales. A variety of statistical moments will be evaluated, including variability, curvature of local peaks, skewness and kurtosis. Statistical moments may be used to detect linearity in variables as directional moments. The spatial structure of landscape variables may be characterised in terms of near, medium and long range autocorrelation (Legendre & Legendre; 1998; Haining, 2003). Similarly, overall periodic patterns of occurrence may be analysed by applying techniques for spectral analysis to reveal patterns at different scales. Broad scale measures detect distributions across a surface, such as trends and clumping. A spatial modelling framework, MapScript, developed by Pullar (2003), will be used to conduct extensive systematic tests on the behaviour of surface textural and spatial statistics in artificial landscapes of different continuous structures. MapScript has a spatial modelling language that allows us to define special operators as neighbourhood templates or functions for the gradient-based pattern variables (Pullar, 2002). A range of surface textural measures and spatial statistics will be evaluated as to how well these pattern variables quantify gradients in landscape structure at local and broad scales.

Output: Evaluation of landscape surface measures/metrics and spatial analysis techniques suitable for quantifying gradients in landscape structure.

Component 3: Testing ecological relevance.
This component relates to Objective 3, and empirically tests the ecological relevance of the surface textural measures and spatial statistics derived from Component 2 for two case study areas in northern Australia. It will involve the following tasks.

Task 1: Fauna survey data will be captured for a sub-tropical forest landscape and a savanna woodland landscape characterised by spatial or spatial/temporal gradients in habitat quality such as tree age, tree density, shrub cover and cover. The sub-tropical case study area will be St Mary State Forest, a dry eucalypt forest in Southeast Queensland with continuous gradients in tree age, tree density and vertical structural complexity. St Mary State Forest was used by McAlpine and Eyre (2002) into the development of Montreal Indicator 1.1e. Target fauna for this study will be arboreal marsupials and diurnal forest birds. Four repeat arboreal and diurnal bird survey data along 72 transects are available from 1993 to 2001 for the study area. We will conduct two additional repeat surveys along the same transects (1 summer and 1 winter) to update existing fauna surveys. The location of the savanna case study will be in north Queensland, and will selected in consultation with Dr Ludwig. We will aim to acquire fauna survey data from other ecological studies in the region, with a preference for studies which include bird species sensitive to spatial variations in the tree-grass ratio, and ground-dwelling mammals and reptiles sensitive to gradients in ground-layer herbaceous and woody vegetation. We expect that there will be gaps in both the temporal and spatial coverage of available fauna data for the tropical savanna case study. For this reason, provision will be made to supplement existing available data with fauna field surveys specifically designed to meet the analysis needs of the project. The habitat preferences and movement behaviour of target assemblages and species for the two case studies will be reviewed in order to gain an appreciation of species habitat preferences and spatial and seasonal movement patterns. Vegetation surveys will be conducted for each fauna survey site to quantify fine-scale habitat attributes. For St Mary State Forest, number of hollow-bearing trees, tree density, overstorey foliage projective cover, vertical structural complexity, plus vegetation composition will be measured for each transect. For the savanna case study, tree and shrub density, ground cover, and fetch distance between grass clumps (landscape leakiness) will be measured.

Output: Comprehensive datasets of fauna presence/absence and abundance for two case-study areas in Queensland.

Task 2: The objective of this task is to map fine-scale variations in habitat quality for the two case study areas. This task will be achieved by acquiring high spatial resolution (e.g., IKONOS or Quickbird with a spatial resolution of 4 m or 2.4 m), multi-spectral satellite image data to provide a continuous map of landscape structure in the targeted environments. Existing high spatial resolution imagery acquired by Dr Ludwig will supplement new remote sensing data for the savanna case study. Habitat quality has been defined as type of vegetation community, and density of vegetation cover. A combination of spectral and spatial classification approaches will be used to define these zones. In particular, neighbourhood or kernel operators will be used to map commonly recurring vegetation structures in the image. Prior to image processing, the expected map output from each type of kernel operator will be identified and a summary table derived to indicate the type of landscape structure able to be highlighted (Strahler *et al.* 1986; Jupp *et al.* 1988; Atkinson and Tate 2000). Kernel operators considered will include spatial-autocorrelation, along with first and second order operators traditionally used in image processing (Haralick 1986). Interpretation of the single-date landscape structure map will be used to identify vegetation structure and the scale(s) of spatial and temporal variation in these structures. This will be done using the continuous landscape conceptual framework developed in Component 1. This approach will provide a unique integration of new technology, extending the type of landscape structures and processes able to be mapped and analysed.

Output: High spatial resolution GIS ready images maps showing forest structural parameters in St Mary State Forest and tropical-savanna vegetation cover parameters.

Task 3: In this task, we will test the ecological relevance surface textural measures and spatial statistics of spatial and temporal gradients in landscape structure (evaluated in Component 2, and applied to habitat quality maps captured in Task 2 of Component 3). The analysis will involve applying an information theoretic approach (Burnham and Anderson 2002) and generalised linear models to rank the capacity of the textural measures and spatial statistics to the predict species occurrence and abundance data captured in Task 1 of this component. Spatial dependence will quantified in both the landscape variable surface and the dependent fauna data (Haining, 2003), while model and parameter uncertainty will be quantified for the generalised linear models (Burnham and Anderson 2002). Based on these analyses, we will identify a core set of landscape surface measures and spatial statistics (20-30) suitable for quantifying spatial gradients in landscape structure. It also will enable an ecological interpretation and associated limitations to be documented for each landscape surface measure from both a structural and functional perspective. The results of these analyses will be synthesised into a matrix summarising the ability of different surface measures and spatial statistics to predict species presence/absence and also abundance according to species habitat preferences and movement behaviours. The ecological relevance of these surface measures in terms of habitat quality/quantity, home range and dispersal movement will be inferred from information captured in the surface measures and spatial statistics.

Output: Synthesis of the ecological relevance of surface textural measures and spatial statistics for different species according to their habitat requirements and movement behaviours.

Component 4: Landscape analysis toolbox.

The final component will develop of a toolbox of surface textural metrics and spatial statistics capable of quantifying continuous variations in the structure of variegated and intact landscapes. The toolbox will be a stand-alone computer package capable of reading GIS raster data sets, and outputting a range of user-specified landscape surface measures, which landscape researchers and conservation biologists can then use to test the influence of landscape structure in variegated and intact landscapes. The package will include add-on features for calculating spatial-autocorrelation in fauna presence/absence and abundance data, and also spatial statistic tools for analysing relationship between two or more continually varying surfaces. It will be accompanied by supporting documentation outlining the ecological interpretation of each surface textural measure and spatial statistic, its mathematical derivation plus any inherent limitations in its application such as sensitive to change in spatial resolution and extent.

Outputs: User-friendly computer-package and support documentation for quantifying gradients in landscape structure.

Research outcomes:

1. Enhanced capacity of researchers and conservation managers to deliver biodiversity outcomes at the landscape-level in landscapes with gradients in structure (e.g., tropical savanna woodlands, sub-tropical eucalypt forests, sub-tidal inshore seagrass, wetlands).
2. User-friendly computer-package and guidelines, readily available to Australian and international researchers, for quantifying gradients in landscape structure using surface textural measures and spatial analysis tools built into the package.
3. Critical review and evaluation of the capacity of existing surface textural measures and spatial analysis techniques to quantify gradients in landscape structure.
4. New tools and concepts for advancing landscape ecology research in terrestrial, aquatic and marine landscapes with a continuous structure, where current discrete patch-mosaic concepts and metrics are not suitable.

E5: National Benefit.

The project will make an important contribution to an Environmental Sustainable Australia (Research Priority 1), especially Priority Goal 5: Sustainable use of Australia's biodiversity. Australia's long-term economic prospects depend on the sustainable use and management of our native vegetation and the conservation of our unique biological diversity. In southern Australia, we face significant challenges in repairing past damage to our land and water resources and restoring our environment for future generations. We expect the landscape analysis tools to be suitable for southern landscapes, especially in moderately fragmented landscapes where boundaries form gradients. The geographic focus of the project is in sub-tropical and tropical regions, where relatively 'intact' landscapes and ecosystems support a rich diversity of native plants and animals. This rich biodiversity attracts hundreds of thousands of international tourists worth billions of dollars each year, and is second only to mining in economic importance. However, species have been lost and more are being lost now as result of habitat modification and biological invasions (Woinarski and Fisher 2003). The Einasleigh Plateau, the Desert Uplands, the Brigalow Belt North and South, and the North Kimberley biogeographic regions have been recently identified by the Commonwealth Minister for Environment as declared biodiversity hotspots that are under threat from human-induced change. The landscape analysis tools and supporting knowledge developed by this study will allow for more effective landscape-level conservation strategies to be developed in these northern regions by assisting researchers and managers to answer key questions about how to manage the structure of native vegetation for the long-term conservation of regional wildlife populations. Disturbance pressures from grazing, fire and thinning on remaining vegetation will continue to affect the quality of habitat for dependent biota, hence the need for landscape-level analysis tools proposed by this project. The project will also enhance long-term conservation efforts in marine ecosystems such as seagrass landscapes, and aquatic ecosystems such as wetlands, where human modification is increasing landscape heterogeneity. The new tools and concepts will allow ecologists to test the importance of landscape context for fauna populations in these environments. For terrestrial, aquatic and marine ecosystems, the project is consistent with the national goal of: reversing the long-term decline in the extent and especially quality of Australia's native vegetation, and the conservation and restoration of native vegetation to maintain and enhance biological diversity, as stated in the National Framework for the Management and Monitoring of Australia's Native Vegetation (Commonwealth of Australia 2001).

E6: COMMUNICATION OF RESULTS

The Chief Investigators and the Partner Investigator already have close research ties with research and natural resource management agencies in northern Australia including CSIRO Sustainable Ecosystems, Northern Territory Department of Infrastructure, Planning and the Environment, Queensland Environment Protection Agency, Queensland Department of Natural Resources and Mines. Contact has already been made regrading the project, and there is a demonstrated strong support from these bodies. It is proposed the liaison committee be formed and meet regularly with the Chief Investigators and the Partner Investigator. This will involve meetings/workshops in order to develop strong interaction with other researchers in the various application environments. The research outcomes will be communicated to the scientific community through peer reviewed journal articles, national and international conferences, and to the wider community through media releases. We will communicate the project to Australian landscape ecologists through the IALE-OZ newsletter, and canvass their input through the same newsletter into the approach and development of landscape analysis tools.

E7: DESCRIPTION OF PERSONNEL

Dr Clive McAlpine (Chief Investigator, 5 days per month): Clive will be responsible for: the overall management of the project, its conceptual development, and play a major role in the remaining research components. He will work closely with the Research Assistant in data acquisition and management, and the supervision of the PhD candidate in the ecological components of the project. He brings to the project considerable research experience in landscape ecology and remote sensing research in forest, woodland and seagrass landscapes. He has successfully supervised four PhD candidates, and is currently principal supervisor of 6 PhD students.

Asoc/Prof Stuart Phinn (Chief Investigator, 4 days per month): Stuart will play an important role in all research components, particularly the evaluation of the landscape surface metrics (Component 2) and the remote sensing of landscape structure (Component 3), and will be responsible for co-supervising the PhD candidate. He brings to the project extensive experience in remote sensing and spatial analysis.

Dr David Pullar (Chief Investigator, 4 days per month): David will play an important role in all research components, particularly the testing and development of the landscape analysis tools, and will be responsible for co-supervising the PhD candidate. He brings to the project extensive experience in spatial analysis and modelling, plus software development.

Dr John Ludwig (Partner Investigator, 2 days per month): John will provide input into Task 2 in Objective 3 and to Objective 4 by helping guide the metric testing and toolbox development. He will also be co-supervisor of the PhD student proposed for the project. He brings to the project extensive experience in landscape ecology and landscape function analysis, plus access to fauna survey data and remote sensing data for the tropical savanna case study.

PhD Candidate The PhD candidate will have a leading role in the ecological aspects of the project, including reviewing the literature, compiling bibliographic data bases, liaising with external researchers for data, conducting the fauna surveys, statistical analysis, and preparation of journal publications.

Research Associate: The major responsibility of the Research Associate will be evaluation of potential landscape surface measures (Component 2), and remote sensing and spatial analysis tasks of Component 3. This will be done in consultation with Dr Pullar, Assoc/Prof Phinn, Dr Ludwig and Dr McAlpine. However, he/she also will have intellectual input into and draw information from the other research components, including the conceptual development (Component 1). He will be responsible for the acquisition, processing and analysis of the remote sensing data, the development of continuous and discrete landscape metrics for the case study areas. He will work closely with other remote sensing researchers within the University of Queensland, and also in Queensland government agencies (e.g., SLATS) and through Dr John Ludwig (PI), CSIRO Sustainable Ecosystems, Atherton.

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