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Landscape scale measurement and monitoring of biodiversity in the Australian rangelands

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Abstract

It is becoming increasingly important to monitor biodiversity in the extensive Australian rangelands; currently however, there is no method capable of achieving this goal. There are two potential sources of relevant data that cover the Australian rangelands, and from which measures of biodiversity might be extracted: traditional field-based methods such as quadrat surveys have collected flora and fauna species data throughout the rangelands, but at fine scale; satellite remote sensing collects biologically relevant, spatially comprehensive data. The goal of this thesis was to provide the spatially comprehensive measure of biodiversity required for informed management of the Australian rangelands. The study specifically focused on the Stony Plains in the South Australian rangelands. To that end the thesis aimed to develop indices capable of measuring and/or monitoring biodiversity from vegetation quadrat survey data and remotely sensed data.

The term biodiversity is so all-encompassing that direct measurement is not possible; therefore it is necessary to measure surrogates instead. Total perennial vegetation species richness (γ-diversity) is a sound surrogate of biodiversity: the category of species is well defined, species richness is measurable, and there is evidence that vegetation species richness co-varies with the species richness of other taxonomic groups in relation to the same environmental variables.

At least two broad scale conventional vegetation surveys are conducted in the study region; the Biological Survey of South Australia; and the South Australian Pastoral Lease Assessment. Prior to the extraction of biodiversity data the quality of the BSSA, the best biodiversity survey, was evaluated. Analysis revealed that false-negative errors were common, and that even highly detectable vegetation species had detection probabilities significantly less than one. Without some form of correction for detectability, the species-diversity recorded by either vegetation survey must be treated with caution.

Informed by the identification of false-negative errors, a method was developed to extract γ-diversity of woody perennials from the survey data, and to remove the influence of sampling effort. Data were aggregated by biogeographic region, rarefaction was used to remove most of the influence of sampling effort, and additional correction removed the residual influence of sampling effort. Finally, additive partitioning of species diversity allowed extraction of indices of α-, β- and γ-diversity free from the influence of sampling effort. However, this woody perennial vegetation γ-diversity did not address the need for a spatially extensive, fine scale measure of biodiversity at the extent of the study region. The aggregation of point data to large regions, a necessary part of this index, produces spatially coarse results.

To formulate and test remotely sensed surrogates of biodiversity, it is necessary to understand the determinants of and pressures on biodiversity in the Australian rangelands. The most compelling explanation for the distribution of biodiversity at the extensive scales of the Australian rangelands is the Productivity Theory, which reasons that the greater the amount and duration of primary productivity the greater the capacity to generate and support high biodiversity. The most significant pressure on biodiversity in the study area is grazing-induced degradation, or overgrazing.

Two potential spatially comprehensive surrogates of pressure on biodiversity were identified. The first surrogate was based on the differential effect of overgrazing on water-energy balance and net primary productivity: water-energy balance is a function of climatic variables, and therefore a measure of potential or expected primary productivity; net primary productivity is reduced by high grazing pressure. The second surrogate was based on the effect of grazing-induced degradation on the temporal variability of net primary productivity: overgrazing reduces mean net primary productivity and rainfall use efficiency, and increases variation in net primary productivity and rainfall use efficiency.

The two surrogates of biodiversity stress were derived from the best available remotely sensed and climate data for the study area: actual evapotranspiration recorded by climate stations was considered an index of water-energy balance; net primary productivity was measured from NOAA AVHRR integrated NDVI; rainfall use efficiency (biomass per unit rainfall) was calculated from rainfall data collected at climate stations and the net primary productivity measure. Finally, the surrogates were evaluated against the index of woody perennial α-, β- and γ-diversity, on the assumption that prolonged biodiversity stress would reduce vegetation species diversity.

No link was found between Surrogate 1 and woody perennial α-, β- or γ-diversity. The relationship of Surrogate 2 to woody perennial diversity was more complex. Only some of the results supported the hypothesis that overgrazing decreases α-diversity and average NPP and RUE. Importantly, none of the results supported the most important part of the hypothesis that the proposed indices of biodiversity pressure would co-vary with woody perennial γ-diversity. Thus, the analysis did not reveal a convincing link between either surrogate and vegetation species diversity. However, the analysis was hampered to a large degree by the climate data, which is interpolated from a very sparse network of climate stations.

This thesis has contributed significantly to the measurement and monitoring of biodiversity in the Australian rangelands. The identification of false-negative errors as a cause for concern will allow future analyses of the vegetation survey data to adopt methods to counteract these errors, and hence extract more robust information. The method for extracting sampling effort corrected indices of α-, β- and γ-diversity allow for the examination and comparison of species diversity across regions, regardless of differences in sampling effort. These indices are not limited to rangelands, and can be extracted from any vegetation quadrat survey data obtained within a prescribed methodology. Therefore, these tools contribute to global biodiversity measurement and monitoring. Finally, the remotely sensed surrogates of biodiversity are theoretically sound and applicable in any rangeland where over-grazing is a significant source of degradation. However, because the evaluation of these surrogates in this thesis was hampered by available data, further testing is necessary.

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Declaration

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Publications arising from this thesis

Refereed publications

Clarke, K.D., Lewis, M.M., and Ostendorf, B. 'False negative errors in a survey of persistent, highly-detectable vegetation species.' *Applied Vegetation Science* (submitted).

Clarke, K.D., Lewis, M.M., and Ostendorf, B. 'Additive partitioning of rarefaction curves: removing the influence of sampling on species-diversity in vegetation surveys.' *Ecological Indicators* (submitted).

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Best student paper at conference (2006) 14th Biennial Conference of the Australian Rangeland Society: Renmark, South Australia.

Proportion of contribution by author

This section is a declaration of the extent of each author's contribution to the two refereed papers arising from this thesis. The extent of each author's contribution is quantified for each of three categories: conceptualisation, realisation and documentation. Finally, each author gives permission for the paper containing their contribution to be included in this thesis.

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Lewis, M.M.	10%	5%	10%	______________
Ostendorf, B.	10%	5%	5%	______________

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Ostendorf, B.	10%	10%	5%	______________

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