1995121385

REMOTELY SENSED INDICATORS OF HABITAT HETEROGENEITY AND BIOLOGICAL DIVERSITY: A PRELIMINARY REPORT

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INTRODUCTION

The relationship between habitat area, spatial dynamics of the landscape, and species diversity is an important theme in population and conservation biology. Of particular interest is how populations of various species are affected by increasing habitat edges due to fragmentation. Over the last decade, assumptions regarding the effects of habitat edges on biodiversity have fluctuated wildly, from the belief that they have a positive effect to the belief that they have a clearly negative effect. This change in viewpoint has been brought about by an increasing recognition of the importance of geographic scale and a reinterpretation of natural history observations. In this preliminary report from an ongoing project, we explore the use of remote sensing technology and geographic information systems to further our understanding of how species diversity and population density are affected by habitat heterogeneity and landscape composition. A primary feature of this study is the investigation of SAR for making more rigorous investigations of habitat structure by exploiting the interaction between radar backscatter and vegetation structure and biomass (Dobson et al. 1992). A major emphasis will be on the use of SAR data to define relative structural types based on measures of structural consolidation using the vegetation surface area to volume ratio (SA/V). Past research has shown that SAR may be sensitive to this form of structural expression (Imhoff 1994) which may affect biodiversity.

SITE DESCRIPTION AND METHODS

In September, 1993, P-, L-, and C-band SAR data were collected over a section of the South Alligator River in Kakadu National Park in the Australian Northern Territory (NT) as part of the Joint NASA/Australia AIRSAR Deployment. The SAR data were supplemented by Landsat TM imagery captured several days later. The area is tropical and is characterized by estuarine flood plains and freshwater billabongs with paleosol (laterite) uplands and scattered sandstone ridges and outcrops. Elevation differences between the flood plains and the uplands are on the order of only a few meters. There are 16 monsoon rain forest floristic groups, in patches on the uplands and low lying soils containing approximately 33 species of overstory trees of Austral-asian origin. The area has a hot-wet hot-dry climate and 85-95% of the 1400 mm in mean annual precipitation occurs between December and March. In August-September, 1994, field data consisting of vegetation structure and other habitat spatial information and census data on the distribution and density of all bird species within the test site were collected along transects orthogonal to a series of habitat edge gradients in the test area. The research described in this report focuses on a set of two primary habitat edges based on vegetation differences. The edges run roughly east-west in orientation spanning approximately 5 deg in SAR range (52 - 57 deg incidence angle). The gradient changes in a north-south direction which is the azimuth direction of the radar. The area was selected because, while the edges are distinct, one edge is predominantly structural in nature while the other is floristic in nature. The structural edge will be identified henceforth as edge A and the floristic one as edge B.

Birds: Ten north-south trending transects were established at random locations orthogonal to the edge lines, with a minimum separation of 100m and a maximum separation of 200m. Along each transect, census points were placed systematically at intervals of 100m. The southernmost census point was established 200m south of the edge between a wet *Melaleuca* forest and a dry *Melaleuca* woodland (edge A). Each of the ten transects spanned edge A and a second edge (edge B) between the dry *Melaleuca* woodland and open mixed *Eucalypt* woodland. Each transect was censused twice (between 1/2 hr and 3 hrs after sunrise) over ten consecutive days; once beginning at the northern end of the transect, and once beginning at the southern end. Transects were selected arbitrarily each morning, and specific pairings of transects were not repeated. At each census point, 5 minute stationary census were conducted. All birds seen or heard were recorded, along with an estimate of their distance from the census point, up to a maximum of 50m. Birds detected at distances greater than 50m were not recorded (Reynolds et al. 1980). For each species, abundance, represented by the number of detections per point count, was plotted against the position of the point along the habitat gradient. Frequency of detection was tested against a uniform distribution (G-test) to identify significant changes in abundance at the two edges. In all cases, a probability of $p<.05$ that the observed changes in abundance were due to chance alone was deemed sufficient to reject the null hypothesis that the detections were distributed randomly along the gradient.

Vegetation: Vegetation data were collected along seven of the bird survey lines using the point-center-quarter (PCQ) method. Point data were taken at 33 m intervals and included: species identification, stem diameter (dbh), height, height to live crown, crown dimensions in x and y, and stem density. In all, more than 200 points on the ground were surveyed compiling measurements for over 1000 individual trees. Measurements for crown components such as branch length, number of branches, and leaf area are being made using photographic methods including hemispherical canopy photography. The PCQ data were divided into nine 100 meter wide geographic zones parallel to edges A and B for statistical analysis. Each zone contains a minimum of 21 PCQ points from which statistics were generated. Results are given for floristic composition and vegetation structure including: mean stem density, dbh, height, biomass, and vegetation surface area to volume ratio SA/V.

SAR Analysis: The SAR analysis is in the correlative phase. The Macsigma0 program written by JPL was used to derive backscatter statistics for the 9 vegetation edge zones. Radar backscatter is reported as $\sigma°$ in dB (m^2/m^2) and is compared to the vegetation (bole) surface area to bole volume ratio (SA/V) and bole biomass.

RESULTS AND DISCUSSION

SAR and Vegetation Structure: The SAR data used in this study successfully identified a series of edaphic driven structural changes across a floristically homogeneous stand of vegetation. Such a change was evident at edge A where a *Melaleuca cajuputi* woodland changed in structure from a tall, closed canopy (zones 1-3) to a more densely stocked formation of smaller individuals (zones 4-6). All of the structural parameters except stem density changed significantly across edge A ($p<.01$, T-test). The SAR data also detected another structural/floristic edge at zone 5 where the *M. cajuputi* changes to a more dense smaller statured stand containing a mixture of *M. cajuputi* and *M. viridiflora*. The bole SA/V changed dramatically in zone 5. All three SAR bands were capable of clearly identifying these changes, yet these changes *were not* as readily discernible on the Landsat TM image. Because the stands in zones 1-6 are nearly monospecific, substantial changes in the canopy opening were required before the ground contribution could alter the otherwise identical TM spectral reflectance from the canopy. Edge B represents the opposite situation from edge A. At edge B there is an abrupt and complete floristic change but the structural differences are more subtle. Only crown volume was significantly different ($p< .01$, T-test). In the case of edge B, bole biomass does change significantly but this is due to the higher bulk density of *Eucalypts* and not to a bole volume difference. The best correlations were achieved between the C-HV, L-VV, P-VV and C-VV, L-VV, P-VV backscatter and bole biomass and SA/V respectively (Figure 1).

Birds and Vegetation Structure: During the census, 1449 positive identifications were made representing 58 species. Here we represent data for three avian species that illustrate the range of responses observed across the habitat gradient. The lemon-bellied flycatcher (*Microeca flavigaster*) responded primarily to floristics (Figure 2a). It was associated with habitats dominated by both *Melaleuca* species, and abundance did not change significantly at the structural edge (edge A). At edge B where vegetation structure did not change dramatically, but where *Melaleuca*-dominated woodland was replaced by mixed *Eucalypt* woodland, the species declined significantly. The brown honeyeater (*Lichmera indistincta*) followed a different pattern. It occurred abundantly throughout the study site (Figure 2b) and its density did not change markedly in the different vegetation communities. Its significant increase at edge B and a smaller increase at zone 5, indicates that this species may be responding to some structural aspects of its habitat. Some significant structural shifts did occur at zone 5 (SA/V) and edge B (crown volume). The yellow oriole (*Oriolus flavocintus*) seems to be strongly associated with wet *Melaleuca* forests (Figure 2c). Within this habitat it occurred with greater frequency at the edge. This species appears to be responding strongly to both floristic and structural elements, generating a more complex edge-associated response.

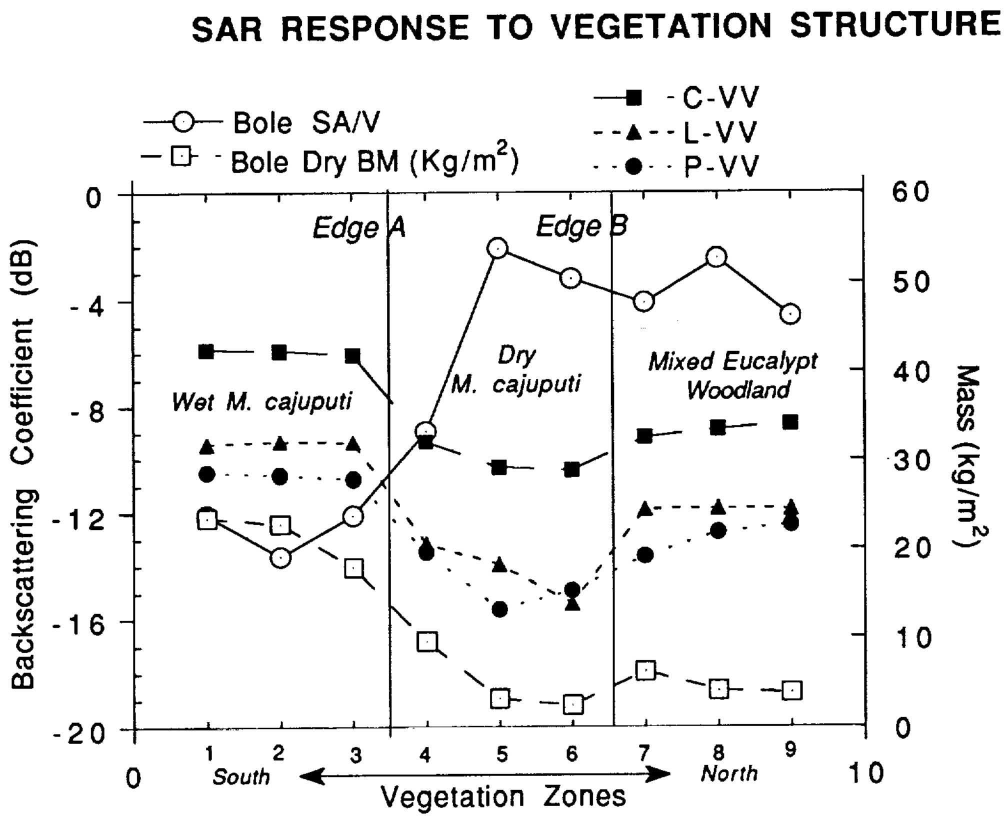


Figure 1. SAR response to vegetation structure and biomass along the habitat gradient. As biomass decreases across the gradient SA/V increases and SAR backscatter decreases. All changes in structural parameters except stem density were significant across edge A, as was SA/V at zone 5 ($p<.01$, T-test). Few structural changes were statistically significant across edge B. Bole volume differences across edge B are not significant, but biomass changes are more evident due to bulk density differences between the *Melaleuca* and the *Eucalypts*.

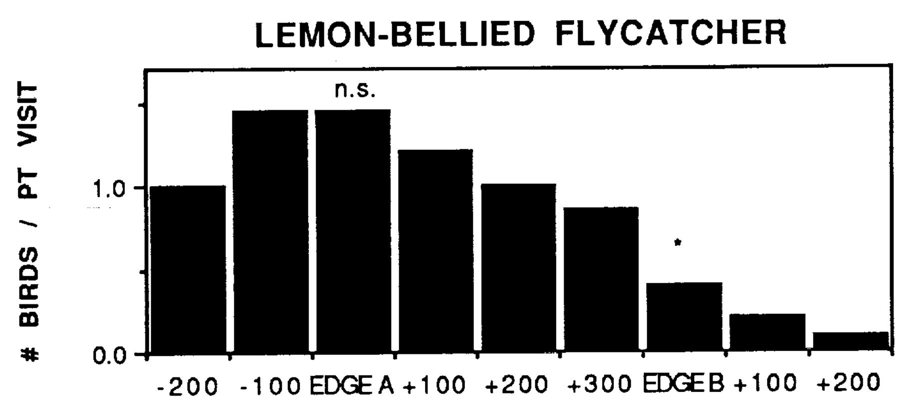
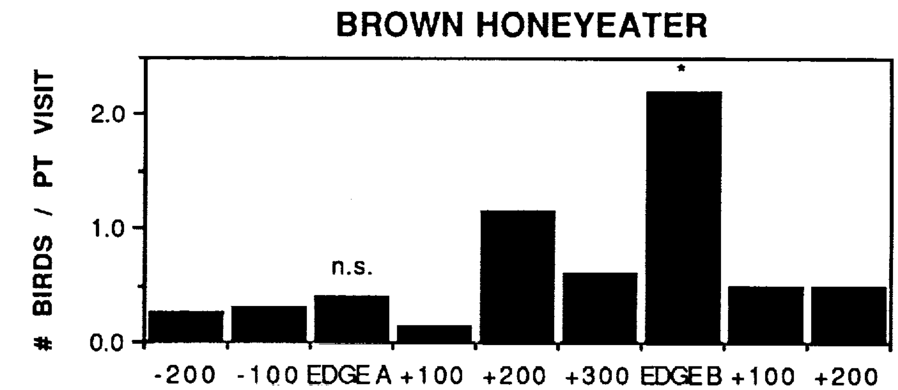
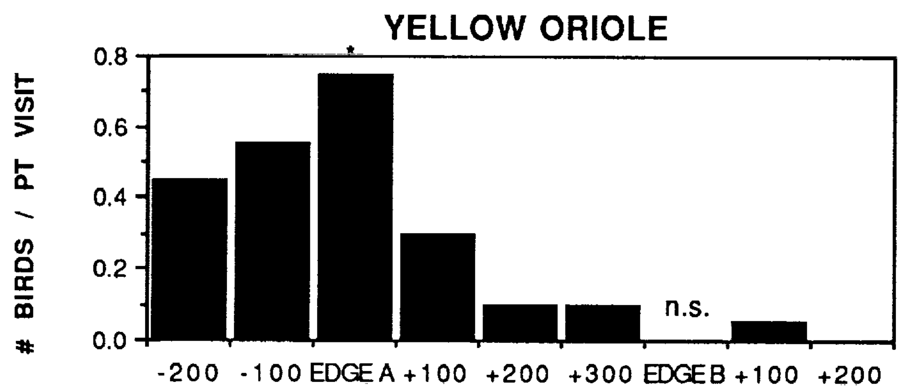


Figure 2a. Abundance response to vegetation for the lemon-bellied flycatcher (*Microeca flavigaster*) which responded primarily to floristics. Change is significant (* = p≤ .05) at edge B but not at edge A (n.s.). Histogram blocks correspond to vegetion zones 1-9 as shown in Figure 1.





Figures 2b and 2c. Top: Abundance response to vegetation for the brown honeyeater (*Lichmera indistincta*). Abundances for this species did not change markedly in the different vegetation communities. Change is significant at edge B (* = p≤ .05) but not edge A (n.s.). Bottom : Abundance response for the yellow oriole (*Oriolus flavocintus*) is strongly associated with wet *Melaleuca* forests. Change is significant (* = p≤ .05) for edge A but not edge B (n.s.). Histogram blocks correspond to vegetion zones 1-9 as shown in Figure 1.

CONCLUSION

Results from this study indicate that bird species are individualistic in their responses to habitat heterogeneity and that edges are potentially powerful factors in determining the abundance of bird species in a heterogeneous landscape. Through the integration of SAR and TM data with field data we were able to isolate trends in floristic and structural components of bird habitats. We found that different bird species responded differently to these structural factors and that SAR data are capable of identifying some of those structural factors. The combination of SAR, multispectral, and species-level ecological data may provide the foundation for a new generation of modeling tools designed to make predictions of relative species abundances in heterogeneous landscapes based on spatial patterns in the distribution of habitat types.

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