# Bird species richness and abundance: The effects of structural attributes, habitat complexity and tree diameter

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## Abstract

Structurally complex habitats influence species richness and abundance through the provision of resources and microhabitats. This study examines the effects of structural attributes, habitat complexity (expressed as habitat complexity score) and tree diameter (expressed as standard deviation of diameter at breast height), on bird species richness and abundance. Projected foliage cover and diameter at breast height of the five closest trees and bird richness and abundance were recorded at the 30 survey sites within the Kioloa Coastal Campus. Regression analyses were conducted between the structural attributes and bird richness and abundance. A statistically significant correlation ($\alpha=0.05$) was found between habitat complexity score and bird richness and abundance. A similar relationship was observed with the standard deviation of diameter at breast height. Land managers can employ these findings to enhance habitat restoration and rehabilitation projects, and to monitor biodiversity outcomes.

## Introduction

Over the last two hundred years, 29 native Australian bird species have gone extinct (Szabo, Khwaja, Garnett, & Butchart, 2012) and this figure is forecasted to reach 39 by 2038 unless biodiversity and land management practices improve drastically (Geyle et al., 2018). The concept of habitat complexity, or the structural attributes of an environment (Smith, Johnston, & Clark, 2014), was first introduced in the classical work ‘On Bird Species Diversity’ by MacArthur and MacArthur (1961), who discovered a positive relationship between foliage height diversity and bird species diversity. Since then, the study of habitat complexity and its effects has proliferated the field of ecological science, with similar correlations being observed in the terrestrial (Gardner, Cabido, Valladares, & Diaz, 1995; Lawton, 1983) and marine domains (Kelaher & Castilla, 2005; Luckhurst & Luckhurst, 1978). Researchers generally seek to identify structural attributes that affect species richness and abundance. They hypothesise that complex habitats offer more potential niches and reduce the possibility of niche overlap as compared to structurally simpler habitats (Klopfer & MacArthur, 1960, 1961).

Integrating the ecological niche theory popularised by Hutchinson (1957) with birds, one can deduce that in structurally complex habitats, birds will have access to a variety of foraging sites from which specialisation can occur, enabling more species to be added into the existing assemblage (Karr, 1990). For example, the presence of ground litter and coarse woody debris in complex landscapes creates the microhabitats required to support the invertebrate community, an important source of food for many bird species (Nilsson, 1979). Apart from food, complex habitats increase the availability of nesting, perching and roosting sites, which are fundamental to birds, especially tree-hollow nesters. For example, Gibbons, Lindenmayer, Barry, and Tanton (2000) established that structural attributes such as tree diameter are associated with the occurrence of tree hollows and this may implicate hollow nesters such as the threatened superb parrot (*Polytelis swainsonii*) (Manning, Gibbons, Fischer, Oliver, & Lindenmayer, 2013).

Tree diameter is also an important stand structural attribute that communicates the health of habitats, ecological functions and the process of ecological succession (Spies & Franklin, 1991), which may affect bird richness and abundance. Thus, complex habitats can increase the availability of resources, decreasing competition and resulting in increased bird richness and abundance (Seddon, Briggs, & Doyle, 2001, 2003).

This paper aims to contribute to existing land management practices and bird conservation efforts by identifying key relationships between structural attributes and bird richness and abundance. Stakeholders can employ these findings to facilitate land restoration projects, habitat rehabilitation and monitoring. The study methods and findings discussed below explore the effects of structural attributes on bird species richness and abundance. In line with the previous observations, it is hypothesised that bird species richness and abundance increase as habitats become more complex.

# Methods

## Study area

The study was carried out at the Kioloa Coastal Campus (KCC) of ANU. KCC is located in the south-eastern coastal district of Shoalhaven, New South Wales (35°32'S; 150°22'E). It encompasses an area of 348 hectares, which borders the foothills of the Murramarang Ranges to the west, the mean high-water mark of the beaches to the east, private lands to the north and Crown land such as the Murramarang National Park to the south (Figure 1).

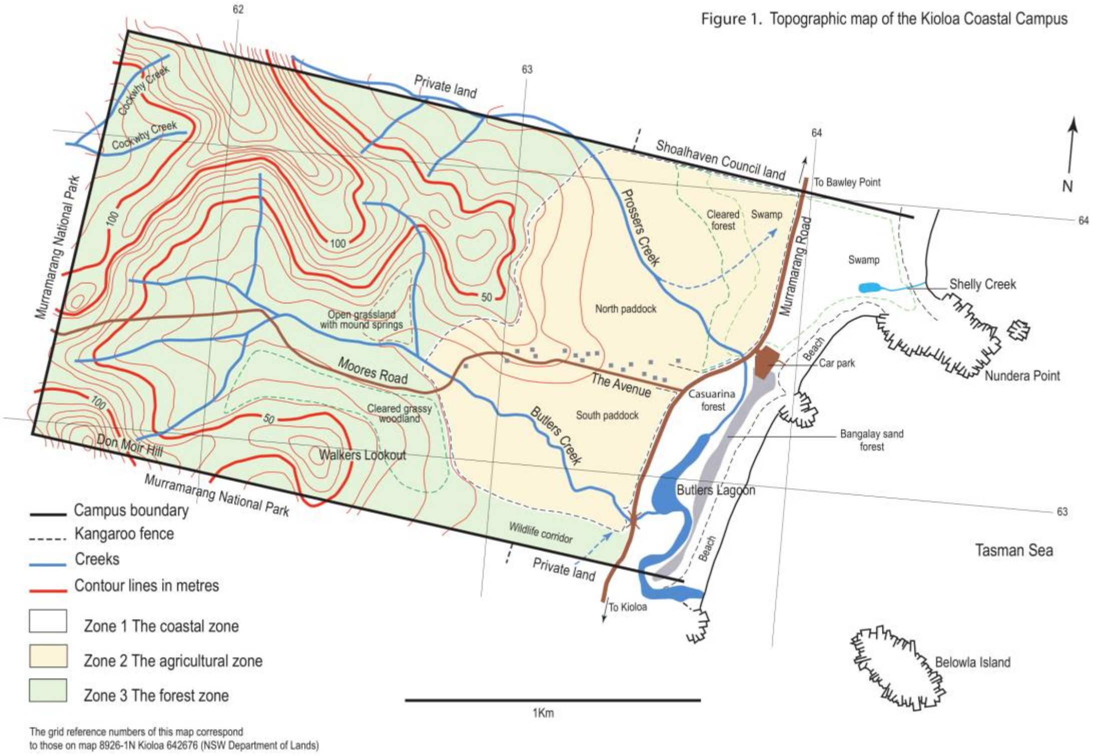

Figure 1: Annotated Map of KCC.

Source: ANU Facilities & Services Division, 2017.

KCC receives a mean annual rainfall of 1,110 mm and experiences mean annual temperature of 13.2°C to 20.6°C (BOM, 2017). Elevation within KCC ranges from 0 to 100 metres above sea level. KCC can be categorised into three major vegetation zones, coastal, agricultural and forest (Figure 1), which reflects on the land use history of the property (Caton, 2007). This study focuses on agricultural and forest zones. The former comprises of cleared pastures and remnant vegetation along creeks and is occupied by tussock grass (*Poa sp.*) and grasses such as ryegrass (*Lolium multiflorum*) and kikuyu (*Pennisetum clandestinum*). The latter can be further classified into regrowth and old growth areas.

The regrowth area comprises of cleared grassy woodlands, with spotted gums (*Corymbia maculata*), prickly beard-heath (*Leucopogon juniperinus*) and orange thorn (*Citriobatus pauciflorus*). The old growth area comprises of southern lowland wet sclerophyll forest and southern warm temperate rainforest. Spotted gums (*C. maculata*), blackbutt (*Eucalyptus pilularis*), bangalays (*E. botryoides*) and stringybarks (*E. spp.*) occupy the sclerophyll forest and bolwarras (*Eupomatia laurina*), lilly pillies (*Syzygium smithii*) and tree ferns (*Dicksonia antarctica* and *Cyathea australis*) occupy the rainforest.

## Bird survey

This study employed a total of 30 survey sites within the KCC and the sites were allocated equally among the agricultural (pasture) and forest (regrowth and old growth) zones (Figure 2).

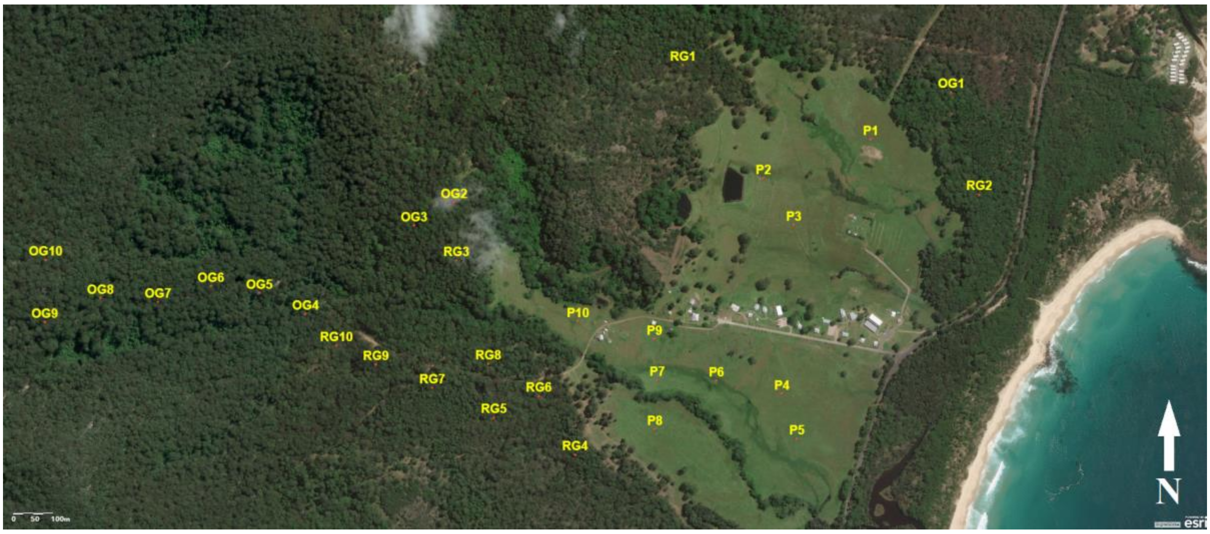

Figure 2: Satellite image of KCC and the location of the 30 survey sites.

Source: Esri, 2017.

Bird surveys were conducted in the early hours of the day following sunrise, between 0700H to 1000H, as bird activity peaks during this period and gradually declines as the morning progresses, as suggested by Robbins (1981). The 30 sites were equally divided among six groups and a trained expert/ornithologist was assigned to each group. The bird surveys were conducted using the single visit point count method as outlined by Laiolo (2002), where all birds seen or heard within a 50-metre radius of the site were recorded. Overflying birds that were passing by were not considered to be using the site and they were not recorded in our study, as suggested by Laiolo (2002). Each site was sampled for five minutes in order to achieve maximum efficiency when recording the number of species per unit effort, as suggested by WP Smith et al. (1993). The total number of birds seen or heard was recorded as bird abundance and the total number of different bird species observed was recorded as species richness.

## Vegetation structure survey

At each site, the dominant species at each level of the stratum (upper, middle and ground) were recorded. The diameter at breast height (DBH) of the five nearest trees was measured using a diameter tape. Breast height is defined as 1.30 metres above the ground (Brack & Wood, 1998). Subsequently, a 100-metre transect was established across the site using the measuring tape. The bearing of the transect was chosen in a direction that was representative of the site's vegetation structure. The point intercept method, which involves the densitometer, was used to determine the presence or absence of foliage cover in the upper and mid stratum, as outlined by Hnatiuk, Thackway, and Walker (2010).

The presence or absence of foliage cover (ground) was conducted in a rudimentary manner but it adhered closely to the point intercept method, where the surveyor's toe on the right boot was used as the intercept point. Foliage cover (ground) consisted of grass tussocks (>10 cm in height), fine herbaceous (<10 cm in height), litter (detached plant material), rock, bare ground and coarse woody debris (>5 cm in diameter). A total of 50 observations were made along the transect, at intervals of 2.00 metres and the projected foliage cover was obtained for each component by dividing the sum of present counts by 50 (total number of observations) and multiplying it by 100 (conversion to percentages).

## Data analysis

With respect to the research question and hypothesis, the dependent variables in this study are defined as the total number of bird species (richness) and the total number of birds (abundance). The independent variables are defined as the standard deviation of DBH of the five closest trees (SD.DBH) and habitat complexity, in terms of the habitat complexity score (HCS). Microsoft Excel was used to perform the bivariate regression analysis between the dependent and independent variables, to determine if a statistically significant relationship exists between the structural attributes and bird species richness and abundance.

Tree DBH data collected at each site was processed through Microsoft Excel using the standard deviation function to obtain SD.DBH. The data was quantified and analysed in terms of SD.DBH as it reflected the logging and disturbance history of the site (McElhinny, Gibbons, & Brack, 2006) and serves as an indicative measure of biological diversity at the site (Buongiorno, Dahir, Lu, & Lin, 1994). The HCS for each site was obtained by inputting the projecting foliage cover for each component into the scoring matrix below (Table 1).

Table 1: The components of the habitat complexity score and method of scoring

| | **Score 0** | **Score 1** | **Score 2** | **Score 3** | **Comments** |
|---|---|---|---|---|---|
| **Component** | 0–10% | 10–20% | 20–50% | >50% | |
| Upper stratum (% cover) | | | | | |
| Mid stratum (% cover) | | | | | |
| Ground cover (% cover)* | | | | | |
| Litter cover (% cover) | | | | | |
| **Component** | 0–5% | 5–10% | 10–15% | >15% | |
| Rock (% cover) | | | | | |
| Coarse wood debris (% cover) | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Bare ground (% cover) | | | | | |
| Litter cover (% cover) | | | | | |
| Total | | | | | Sum** = |

*Comprises of projected foliage cover data of grass tussocks and fine herbaceous.

**Refers to the sum of the total score for each scoring column (0–3).

Source: Table created by the author, based on Catling and Burt (1995) and Watson, Freudenberger, and Paull (2001).

The scoring matrix is based on Catling and Burt (1995) and Watson, Freudenberger, and Paull (2001) and has been adapted for this study. The modifications consisted of assigning new per cent cover values for each score under rocks, coarse woody debris and bare ground, to capture a greater spread of the data collected. Additionally, the ground cover component in the matrix includes both grass tussock and fine herbaceous projected foliage cover data.

# Results

## Bird species richness and abundance

A total of 645 individual birds belonging to 44 species were recorded during the bird survey. Bird species richness ranged 0–9 species at the pasture sites (2.90 ± 1.02; mean ± standard error), 7–18 at the regrowth sites (12.50 ± 1.01) and 10–16 at the old growth sites (12.70 ± 0.68). Bird species abundance ranged 0–22 at the pasture sites (7.40 ± 2.65), 15–55 at regrowth sites (30.60 ± 3.39) and 22–38 at the old growth sites (26.5 ± 1.74).

## Vegetation structure

Tree DBH ranged from 5.00 cm to 72.00 cm at the regrowth sites (28.00 cm ± 2.57) and from 3.50 cm to 350.00 cm at old growth sites (63.34 cm ± 7.50). No trees were detected at the pasture sites. The range and mean projected foliage cover for each habitat type is presented in Table 2.

Table 2: Range and mean of projected foliage cover for each component for each habitat type

| **Habitat type** | **Upper stratum, %** | **Mid stratum, %** | **Ground cover, %** | **Litter cover, %** | **Rock, %** | **Course woody debris, %** | **Bare ground, %** |
|---|---|---|---|---|---|---|---|
| Pasture | 0 | 0 | 84%–100%<br>87% ± 8.76 | 8%–16%<br>4% ± 1.91 | 0%–2%<br>0% ± | 0%–2%<br>0% ± | 0%–10%<br>1% ± 0.99 |
| Regrowth | 54%–96%<br>74% ± 3.79 | 6%–48%<br>25% ± 3.70 | 4%–48%<br>31% ± 4.84 | 30%–90%<br>65% ± 5.82 | 0%–26%<br>5% ± 2.59 | 0%–6%<br>3% ± 0.82 | 0%–2%<br>1% ± 0.33 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Old growth | 22%–92%<br>67% ±<br>6.08 | 14%–90%<br>42% ±<br>7.31 | 0%–64%<br>17% ±<br>6.72 | 2%–94%<br>67% ±<br>9.13 | 0%–14%<br>2% ± 1.51 | 0%–18%<br>8% ± 1.81 | 0%–14%<br>3% ± 1.34 |

Source: Author's summary of fieldwork data.

The dominant species at the ground stratum was identified as kikuyu (*P. clandestinum*) for pasture sites, cogon grass (*Imperata cylindrica*) for regrowth sites and austral bracken (*Pteridium esculentum*) for old growth sites. The dominant species at the middle stratum was identified as native blackthorn (*Bursaria spinosa*) at the regrowth sites and wild yellow jasmine (*Pittosporum revolutum*) for old growth sites. The dominant species at the upper stratum was identified as spotted gums (*C. maculata*) for both regrowth and old growth sites.

## Bivariate regression analysis, richness

A significant positive correlation was observed ($R^2 = 0.62$, $p$ = <0.001) between HCS and the total number of bird species (richness) (Table 3). A similar relationship was observed ($R^2 = 0.39$, $p$ = <0.001) between SD.DBH and the total number of bird species (richness) (Table 3).

Table 3: Results from linear regression analysis for predicting bird species richness

| **Independent variable** | **Coefficient** | **Standard error** | **Confidence interval (a=0.05)** | $R^2$ | **F** | **t-value** | ***p*-value** |
|---|---|---|---|---|---|---|---|
| HCS | 1.21 | 0.18 | 0.84–1.57 | 0.62 | 46.08 | 6.79 | <0.001 |
| SD.DBH | 0.13 | 0.03 | 0.07–0.20 | 0.39 | 17.81 | 4.22 | <0.001 |

Source: Author's summary of fieldwork data.

Both relationships are illustrated by the graphs in Figures 3 and 4, respectively.

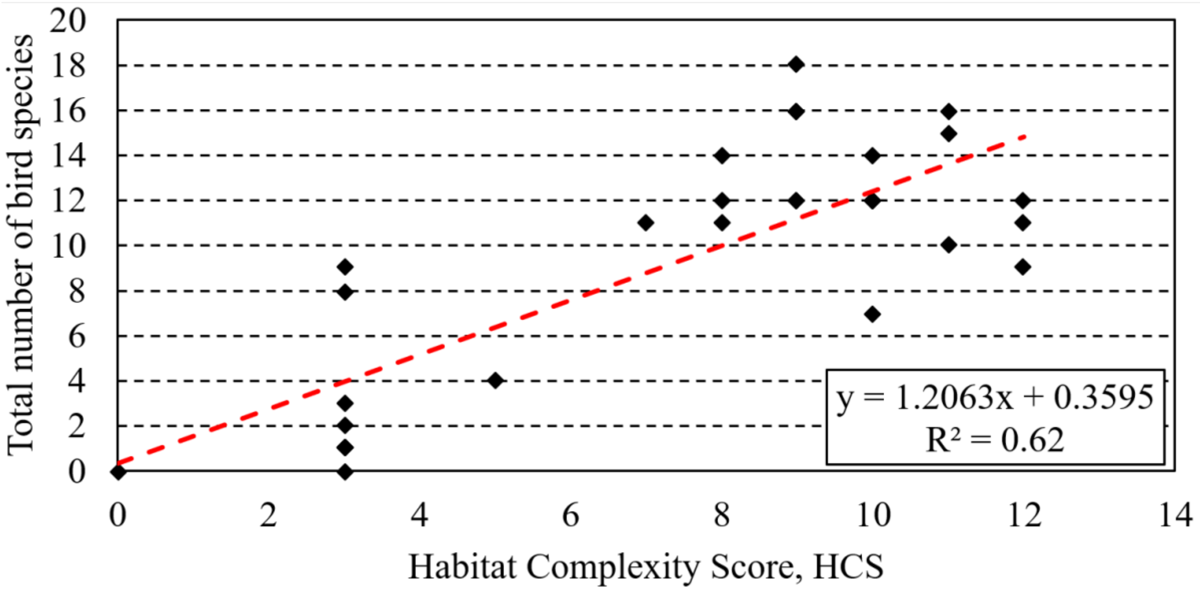

Figure 3: Bivariate linear regression analysis of total number of bird species (richness) with HCS.

Source: Author's summary of fieldwork data.

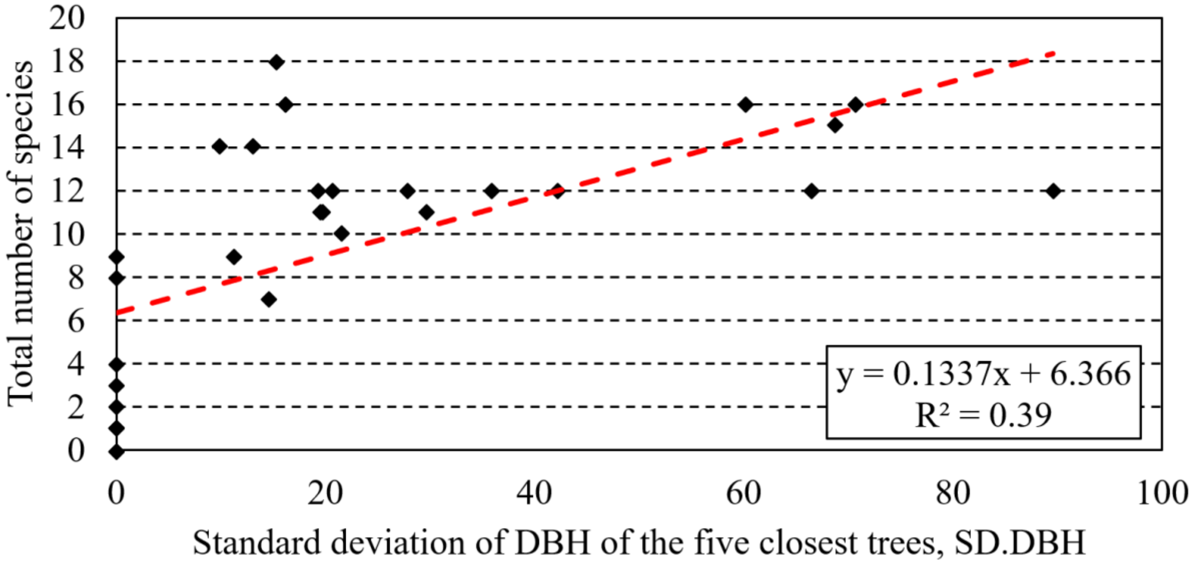

Figure 4: Bivariate linear regression analysis of the total number of bird species (richness) with SD.DBH.

Source: Author's summary of fieldwork data.

### Bivariate regression analysis, abundance

A significant positive correlation was observed ($R^2 = 0.48$, $p$ = <0.001) between HCS and the total number of birds (abundance) (Table 4). A similar relationship was observed ($R^2 = 0.14$, $p$ = 0.043) between SD.DBH and the total number of birds (abundance) (Table 4).

Table 4: Results from linear regression analysis for predicting bird species abundance

| **Independent variable** | **Coefficient** | **Standard error** | **Confidence interval (a=0.05)** | $R^2$ | **F** | **t-value** | **p-value** |
|---|---|---|---|---|---|---|---|
| HCS | 2.57 | 0.50 | 1.54–3.60 | 0.48 | 26.16 | 5.11 | <0.001 |
| SD.DBH | 0.72 | 0.34 | 0.002–1.41 | 0.14 | 4.50 | 2.12 | 0.0043 |

Source: Author's summary of fieldwork data.

Both relationships are illustrated by the graphs in Figures 5 and 6, respectively.

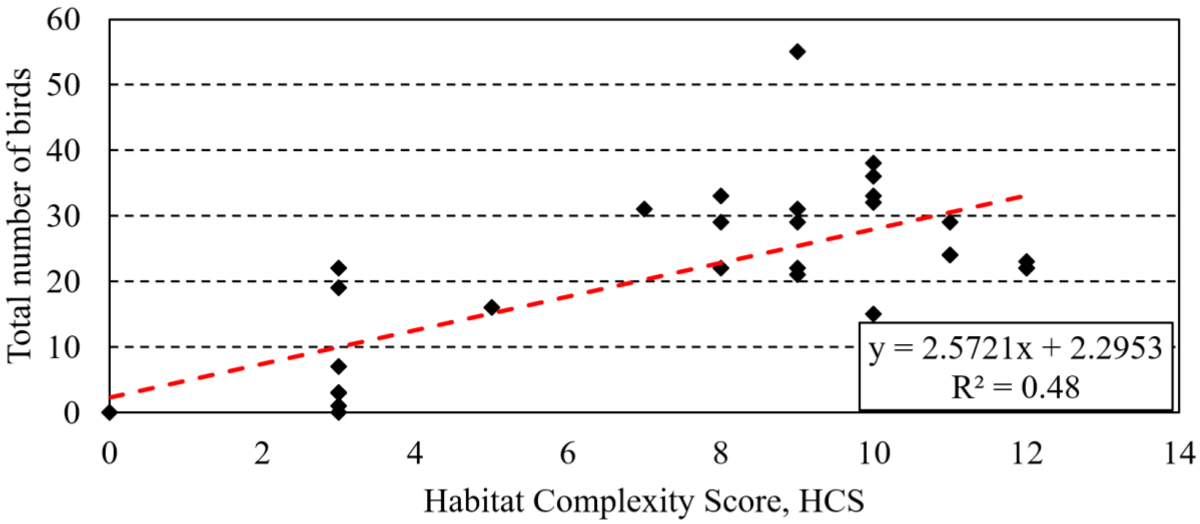

Figure 5: Bivariate linear regression analysis of the total number of birds (abundance) with the HCS.

Source: Author's summary of fieldwork data.

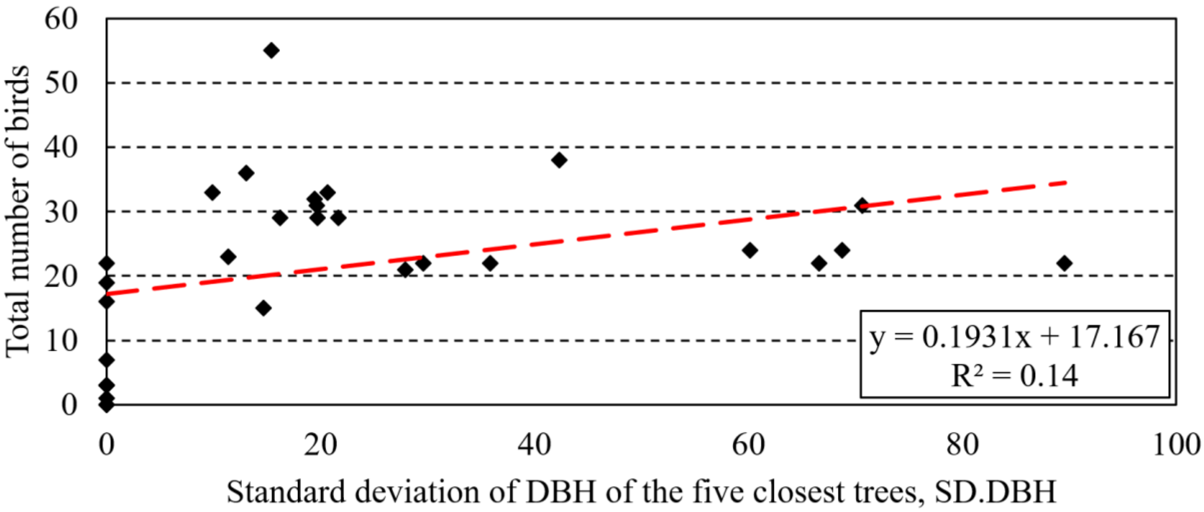

Figure 6: Bivariate linear regression analysis of the total number of birds (abundance) with the variation in DBH of the five closest trees.

Source: Author's summary of fieldwork data.

# Discussion

This study investigated the relationship between structural attributes and bird species richness and abundance. Results supported the hypothesis that bird richness and abundance increase as habitats become more complex. That is, a statistically significant correlation was found between HCS and bird richness and abundance, and a similar relationship was observed with SD.DBH.

## Bird richness and abundance with HCS

The regression analysis yielded a significant correlation between habitat complexity, expressed in terms of HCS, and bird species richness and abundance. Based on the results, 62 per cent and 48 per cent of the variance in richness and abundance respectively can be accounted for by habitat complexity. This implies that bird species richness and abundance increase in proportion to habitat complexity. This relationship can be explained by structural attributes found within each survey site. The absence of trees within pasture sites effectively limits the richness and abundance of birds as there are no incentives for hollow-nesting birds to be present, since the habitat offers no nesting sites (Newton, 1994).

The absence of trees also meant that the in-situ production of coarse woody debris would be non-existent and litter would be limited to wind transportation and ground production, preventing the formation of suitable microhabitats that would allow invertebrates to thrive (Berg et al., 1994), disincentivising insectivorous birds. The absence of upper and mid-canopy cover in the pasture sites may generate unsuitable temperature conditions, negatively affecting bird species richness (Pearman, 2002). Importantly, the low structural complexity of the pasture sites, relative to regrowth and old growth, limits the availability of ecological niches for birds to specialise in, increasing competition and restricting the realised niche to the most adept (Keller & Lloyd, 1994).

Conversely, in the regrowth and old growth sites, the increased structural complexity facilitates the division of habitat resources among different bird species (Hurlbert, 2004). This reduces competition and allows for niche specialisation, enabling greater richness (Van Den Meersschaut & Vandekerkhove, 2000).

## Bird richness and abundance with SD.DBH

Based on the regression analysis, 39 per cent and 14 per cent of the variance in richness and abundance respectively can be accounted for by SD.DBH. This implies that bird species richness and abundance increase in habitats where both old (larger DBH value) and young (smaller DBH value) trees coexist. Older trees are more likely to have experienced stochastic heat stress events such as bushfires, which promotes the process of hollow formation in addition to natural formation with age (Adkins, 2006). Younger trees are also not exempted from such events and can develop hollows as a result of fire (Gibbons et al., 2000). Thus, increased hollow abundance can be expected in trees of larger diameter (Gibbons et al., 2000; Lindenmayer, Cunningham, Donnelly, Tanton, & Nix, 1993).

The presence of hollows does not equate to greater bird species richness or abundance as birds are not the only fauna that use hollows and birds prefer hollows with entrances similar to the size of their body width (Goldingay, 2009). The resulting abundance in tree hollows of varying sizes due to the presence of older and younger trees increases the likelihood of hollow suitability for birds. This reduces competition among birds for nesting sites, increasing breeding density and promoting greater bird richness and abundance (Newton, 1994).

Most importantly, SD.DBH reflects on the assortment of microhabitats present at the stand (Acker, Sabin, Ganio, & McKee, 1998; Van Den Meersschaut & Vandekerkhove, 2000). The variation observed in the old growth forests, where both young and old trees were observed to coexist, also suggests a rich habitat with a variety of niches and resources (Temple, Mossman, & Ambuel, 1979). This allows for specialisation and reduces niche overlap, decreasing competition and relaxing the realised niche.

## Limitation of study

Regarding the experimental design of this study, the location of some survey sites (Figure 2) appears to have been placed at regular intervals along Moores Road for the purpose of accessibility. This may introduce additional variables into our data, as the road is a form of human interference and has changed the landscape around it. The survey sites can be improved through randomised allocation within the forest zone and a buffer can be established to prevent a site from being allocated within a certain distance from the road.

Additionally, the collection of the projected foliage cover data was conducted in a subjective manner, where some groups established transect in a bearing that prioritised accessibility over the accurate representation of the site. This issue can be mitigated by ensuring that surveyors are dressed and geared properly for the job, to reduce and remove any hesitation regarding fieldwork. Geographic Informational Systems (GIS) can also be used to remotely sense certain components of the projected foliage cover, to improve the replicability and the precision of data collected.

Bird species richness and abundance may not have been captured accurately at some of the survey sites due to the way surveys were conducted. Bird activity declines as the morning progresses, as suggested by Robbins (1981) and this would mean that the bird surveys conducted by groups for the last few sites would reflect a lower bird species richness and abundance. This issue can be resolved by ensuring that the survey team is prepared before sunrise so that survey can be conducted within the golden hour of after sunrise. The number of bird surveys conducted can also be increased to reduce the effect of natural variation, increasing precision, and the flow of the sites to survey can be randomised to reduce the effect imposed by the time of day on the bird data.

# Implications

This study has established the effects of structural attributes, habitat complexity and tree diameter on bird species richness and abundance. Land managers and conservationists can employ the findings of this study to better manage their landscape, such as retaining mature hollow-bearing trees during timber extraction or prescribing regular fires to promote hollow formation. Bird habitats can also be deliberately restored or enhanced by tweaking the settings of structural attribute components, such as coarse woody debris and litter cover, which support the invertebrates that most birds feed on.

Alternatively, trees with differing growth rates can be planted to create variability in tree diameter, which enhances microhabitat diversity and resource availability. Importantly, this study highlights the importance of an evidence-based management approach in promoting positive biodiversity outcomes, and the value of future research in stemming the mass decline of Australia's biodiversity.

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