IMPACTS OF BIRD WATCHING ON COMMUNITIES AND SPECIES

LONG-TERM AND SHORT-TERM RESPONSES IN RAINFOREST AND EUCALYPT HABITATS

By Darryl Jones and Thomas Nealson

SUSTAINABLE TOURISM CRC

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Abstract

Although an apparently benign form of nature-based tourism, overseas studies on the activities associated with bird watching have shown significant impacts on birds in numerous important ways. In the first comprehensive study of the impacts of bird watching on birds undertaken in Australia, we studied the structure of avian communities and the disturbance distances of selected species in sites within both rainforest and eucalypt habitats in southeast Queensland. By comparing key variables of birds living near disturbed (picnic grounds) and semi-disturbed (walking tracks) areas with those of birds living in undisturbed areas, we sought to quantify the influence of different levels of disturbance. We found highly significant differences between the numbers of species, numbers of individuals and disturbance distances in almost all comparisons performed. Our results showed clearly that bird watching, while of apparently 'low-impact', had a similar influence as much greater levels of human activity.

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Summary

Although apparently benign when compared with consumptive forms of wildlife recreational activities, bird watching has been shown to impact negatively on wildlife populations. Although interest in the actual impacts of recreational activities – including bird watching – on wildlife has increased markedly in recent years, recreational activities in general are well appreciated but poorly understood. Previous studies have pointed out that some of the methods commonly used by researchers to assess impacts may be too coarse to discern the meaningful findings.

In the present study we overcame some of these constraints by undertaking a detailed study of the possible impacts of bird watching by both observational and experimental techniques for populations and selected species at different levels of disturbance:

- We used well-used rainforest and eucalypt locations and compared the bird communities there with undisturbed areas in southeast Queensland, one of Australian premier tourist destinations.
- We selected six of these as study locations, three in rainforest (O'Reilly's and Binna Burra, within Lamington National Park, and Springbrook National Park) and three in eucalypt habitat (Booloumba Creek and Charlie Moreland Park in Kenilworth State Forest and Amamoor State Forest). This provides us with three replicates of each habitat type.
- We incorporated four measures of disturbance into our experimental approach in an attempt to move beyond key limitations of previous similar work. Our approach allowed meaningful comparisons of the responses of both communities and specific species of birds to two different levels of human disturbance with those in completely undisturbed areas.

Objectives of Study

The two primary aims of the study were:

1. To compare avian community structure (in terms of species richness and numbers of individuals) at different levels of disturbance.
2. To compare disturbance distances of selected species and groups of species at different levels of disturbance

Methodology

The long-term and short-term responses of birds to the activities typically associated with bird watching were studied at six locations in southeast Queensland, Australia, during January-March 2002.

- At each site, three levels of disturbance were determined, based primarily on the amount of human activity. The most disturbed areas ('Disturbed': D) were situated in the picnic grounds and clearings near the main carpark and camping facilities of each location. 'Semi-disturbed' (SD) were areas experiencing low but regular or continuous levels of human disturbance, normally due to the movements of small parties of people walking along the tracks. The least disturbed areas ('Undisturbed': UD) were situated away from all human activity, more than 1 km from any picnic or camping areas.
- The structure of avian communities was determined using fix-width transects and point counts, techniques are recommended for reliable assessments of density and for efficient counts of species richness respectively. Each transect was 100x20 m and was traversed at a slow pace with minimal disturbance to surrounding vegetation.
- Four measures of disturbance distance, were recorded for each experimental interaction: (1) The distance (m) between the focal individual and the observer when bird was first detected; (2) The distance (m) between the focal individual and the observer at the time of the bird's first reaction (the 'alert' distance); (3) The distance (m) the bird moved away following its first reaction; (4) The total distance (m) moved by the focal individual away from the observer.

Key Findings

- The mean number of species in undisturbed sites was significantly greater than both semi-disturbed and disturbed sites in both rainforest and eucalypt areas. For the rainforest sites, the largest group of species were those found commonly in all disturbance levels. Surprisingly, many of these species were equally abundant in all disturbance levels. In contrast to the rainforest sites, the largest group of species associated with eucalypt sites were found only in the disturbed sites.

- Large non-ground species: There were no differences in the first three mean disturbance distances for any disturbance level but distance 4 (the distance the bird moved away from the intruder) was significantly longer in undisturbed sites.
- Small non-ground species: In rainforests, the four mean disturbance distances were significantly different for all disturbance level. For eucalypt species, the results were similarly strong.
- Large ground species: All comparisons by disturbance level were very significantly different.
- Small ground: All but distance 1 were found to be significantly different for rainforest species but not for eucalypt species.
- The large number of relatively common species found at similarly high numbers in sites at each disturbance site is of particular interest. Although some of these species were clearly more abundant in the disturbed sites due to the attraction of anthropogenic food resources (most obviously crimson rosella, pied currawong, and laughing kookaburra), most were not.
- Possibly, the most unexpected result was the extent to which some species (e.g. Lewin's honeyeater, green catbird, black-faced monarch) appeared unaffected by disturbance level, occurring at almost identical numbers at each level.
- Almost every aspect of this study confirmed that birds were significantly influenced by the activities of humans; compared to those living in completely undisturbed locations, birds living in locations experiencing both high or moderate levels of disturbance were characterised by significantly lower species richness, lower numbers of individuals, and greater disturbance distances. Importantly, according to the various variables measured here, there appeared to be virtually no difference between the two levels of disturbance as employed in this design. This would seem to indicate that birds respond similarly to a range of human activities.

Future Action

- These results provide further confirmation that even apparently benign activities such as bird watching can have a marked effect on bird populations They also add general support to observations that birds will avoid humans if possible and prefer undisturbed over disturbed habitats.
- Future work is required to assess long-term impacts of bird watching on reproductive and foraging ecology in areas of differing levels of disturbance.
- Experimental studies are required to assess the potential effectiveness on different 'buffer distances' in a wider variety of habitat types.

Chapter 1

Introduction

Bird watching is one of the fastest growing recreational activities in the Western world. In the United States alone, recent estimates suggest that as many as 60 million people regularly watch birds (Hall & O'Leary, 1989), many times more than that of traditional pursuits such as angling and hunting (Kerlinger & Brett, 1995). Indeed, it is now clear that the number of participants in bird watching has grown dramatically during the past few decades while participation in consumptive form of wildlife-based recreation has fallen (Flather & Cordell, 1995). Similar trends are apparent in many other countries, including Australia (Jones & Buckley, 2001), although there is typically less definitive data available for these places.

Although seemingly benign when compared with consumptive forms of wildlife recreational activities, non-consumptive wildlife-based pursuits have also been shown to impact negatively on wildlife populations (Boo, 1990; Knight & Cole, 1995a, Wearing & Neil, 1999). Knight and Cole (1995a) classify the impacts of bird watching (as one form of nature viewing) as a direct form of 'disturbance' and conceptualise a variety of responses by the species and communities involved. Some responses may be immediate, such as the temporary leaving of the area, while others may be more long-term in effect. For example, when disturbed by passing humans, both pinked-footed geese *Anser brachtrhnchus* and New Zealand dotteral *Charadrius obscurus* chicks spent less time foraging (Gill, Sutherland & Watkinson, 1996, Lord, Waas & Innes, 1997), while European oystercatchers *Haematopus ostralegus* undertook significantly less parental care when disturbed by humans (Verhulst, Oosterbeek & Ens, 2001). While the reactions of the birds measured in each of these studies was proximate and immediate, each could have far-reaching longer-term implications such as reduced survival of chicks or eventual abandonment of the site (Knight & Cole, 1995b). Indeed, numerous studies have now confirmed more generally that even moderate levels of human disturbance can significantly influence long-term patterns of bird foraging behaviour, patch selection, and reproductive outcomes (Giese, 1998; Burger & Gochfield, 1998; Fernández-Juricic, 2000).

For such reasons, interest in the actual impacts of recreational activities on wildlife has increased markedly in recent years (Knight & Gutzwiller, 1995; Gill et al., 2001). Nonetheless, and despite a huge amount of research in a wide variety of situations and countries, many fundamental questions remain unanswered (Carney & Sydeman, 1999; Gill et al., 2001; Blumstein, Anthony, Harcourt & Ross, 2003). Indeed, little has changed since Knight and Cole (1995a) stated that "recreational activities disturb wildlife are well appreciated but poorly understood." (p.61). In their review of the existing literature, these authors identified numerous weaknesses that seriously undermined the applicability of many otherwise important findings. These included an over-emphasis on short-duration investigations and a general lack of adequate controls and replication. Moreover, almost all studies lacked a long-term perspective, focussing rather on immediate and easily obtained behavioural data.

More recently, several workers (see, for example, Fernández-Juricic, Jimenez & Lucas, 2001; Gill et al., 2001) have pointed out that some of the methods commonly used by researchers may be too coarse to discern the meaningful reactions of birds to observed or experimentally induced disturbance. In particular, these authors suggest that assessments based on a bird's 'flight distance' (the distance between an animal and an approaching human at which point the individual flees) may be an inappropriate metric on which to base management decisions designed to minimise human impacts. Gill et al. (2001) argue that flight distances may be heavily influenced by numerous factors, including existing level of exposure to human presence and especially the nature of the habitat. As an alternative, Rodgers and Smith (1997) have suggested that 'alert distance' (The distance between an animal and an approaching human at which point alert behaviours are evident) may be a more appropriate measure for establishing minimum approach distances.

In the present study we sought to overcome some of these constraints by undertaking a detailed study of the possible impacts of bird watching by both observational and experimental techniques for populations and selected species at different levels of disturbance. We used existing well-established forested locations frequently used by large numbers of nature-based recreationists, each of which had experienced many decades of sustained visitation. As a result, the bird species and communities resident in these areas will have had a long period of time to adapt or react; thus any long-term influences should be evident in the composition of the bird communities subject to disturbance.

Such a comparison obviously requires control sites, and these were carefully selected from within the same ecological area but completely removed from all disturbance by humans (these sites were termed 'Undisturbed'). In addition, the locations experiencing disturbance by humans were divided into two levels of disturbance based on the main forms of activities that typically occur there. For 'Disturbed' sites, we used open-areas within the forested reserves were the normal activities were picnicking, low-intensity games and casual nature observations, usually undertaken in family parties but often at high densities. The second level, termed ‘Semi-disturbed’ occurred on existing walking tracks some distance inside the forested reserve. These sites were more typically of normal bird watchers: single or a few individuals, walking steadily though with numerous stops.

We also sought to obtain information applicable to southeast Queensland generally rather than to specific locations. As well as containing the two fastest growing regions in Australia (http://www.abs.gov.au), southeast Queensland is one of Australian premier tourist destinations, attracting millions visitors each year from both domestic and international sources. Many of these visitors undertake short-term journeys to a number of National Parks and State Forests in the hinterlands of the Sunshine Coast and Gold Coast. These reserves are densely vegetated areas of either subtropical rainforest or eucalypt-dominated dry sclerophyll forest. We selected six of these as study locations, three in rainforest (O’Reilly’s and Binna Burra, within Lamington National Park, and Springbrook National Park) and three in eucalypt habitat (Booloumba Creek and Charlie Moreland Park in Kenilworth State Forest and Amamoor State Forest). This provides us with three replicates of each habitat type.

Careful censuses of the species composition of the avian communities found in disturbed, semi-disturbed and undisturbed sites in each of the study locations should provide a useful means of comparing the long-term effects of different amounts of human disturbance. In addition, we also wanted a method that would enable us to assess how different species respond to the presence of humans. Knight and Temple (1995) have noted that wildlife species generally react to human disturbance in one of three ways: they habituate; they are attracted; or they avoid the disturbance. Numerous studies, investigating these responses in a wide variety of contexts and species (Ydenberg & Dill, 1986; Holmes, Knight, Stegall & Craig, 1993; Carney & Sydeman, 1999) suggest that, while intraspecific variation is frequently considerable, there is strong evidence, than the responses are highly species-specific (Blumstein et al*.,* 2003). In other words, species may differ markedly in their reactions to humans; with some quickly habituating to their presence and others moving away form disturbed areas permanently. Such reactions will have significant implications for the communities of species found in locations experiencing differing levels of human visitation.

The fact that animals typically flee from approaching humans has been the basis for a considerable amount of research into the impacts of humans on wildlife. Although this “deceptively simple” (Blumstein et al*.,* 2003, p. 97) observation has often been used in studies attempting to qualify human disturbance of wildlife, recent reviews of much of his work have found inconsistent use of techniques, lack of replication, and disregard for many highly influential variables such as distance to refuges, group size and other features (Knight & Cole, 1995a, Richardson & Miller, 1997). Nonetheless, appropriately employed, experimental ‘disturbance distances’ approaches have yielded valuable insights into wildlife responses to the presence of humans and there results are being applied widely in attempts to minimise the impact of humans (e.g., Giese, 1998, Richardson & Miller, 1997). However, as noted above, this metric has also been criticised as being too ‘coarse’ for the purpose of establishing levels of tolerance (Fernández-Juricic et al., 2001; Gill et al., 2001) with the more sensitive measure of ‘alert distance’ being recommended as an alternative (Rodgers & Smith, 1997). To enable comparisons with earlier work as well as providing our own assessment of tolerance, we have incorporated both measures into our experimental approach.

In the present study we attempted to move beyond several key limitations of previous similar work by designing an approach that would allow meaningful comparisons of the responses of both communities and specific species of birds to two different levels of human disturbance with those in completely undisturbed areas. These responses would be assessed by both non-intrusive observations as well as experimental intrusions, and would be replicated in existing recreational locations in the two main habitat types of southeast Queensland, subtropical rainforest and eucalypt forest.

Within this context, the two primary aims of the study were:

1. To compare avian community structure (in terms of species richness and numbers of individuals) at different levels of disturbance.
2. To compare disturbance distances of selected species and groups of species at different levels of disturbance.

Chapter 2

Methods

Study Sites

The long-term and short-term responses of birds to the activities typically associated with bird watching were studied at six locations in southeast Queensland, Australia, during January-March 2002. Three sites in each of the two principal vegetation types of the region, subtropical rainforest and dry sclerophyll eucalypt forests, were used (Table 1). Detailed description of each site can be obtained from the Queensland Environmental Protection agency website (http://www.epa.qld.gov.au/parks). Each site was chosen as representative of well-known, popular bird watching venues and although numbers typically peaked in summer holiday periods, large numbers occurred in all seasons. While many different recreational activities were carried out in the vicinity of each site, by far the most common activities were low-impact walking and nature observations.

Table 1: Summary of study site locations for southeast Queensland

Name of site	General Location	Distance (km) from Brisbane
Rainforest Sites (Gold Coast hinterland)		
O'Reilly's (OR)	Lamington National Park	105
Binna Burra (BB)	Lamington National Park	110
Springbrook (SP)	Springbrook National Park	90
Eucalypt Sites (Sunshine Coast hinterland)		
Booloumba Creek (BC)	Kenilworth State Forest	110
Charlie Moreland Park (CM)	Kenilworth State Forest	120
Amamoor (AM)	Amamoor State Forest	145

At each site, three levels of disturbance were determined, based primarily on the amount of human activity. The most disturbed areas ('Disturbed': D) were situated in the picnic grounds and clearings near the main carpark and camping facilities of each location. These areas always experienced the highest visitor numbers and associated activities, as well as the greatest attraction in terms of supplementary food resources. Although many birds could be seen in these areas, the predominant recreational activities were picnicking and informal games.

'Semi-disturbed' (SD) were areas experiencing low but regular or continuous levels of human disturbance, normally due to the movements of small parties of people walking along the tracks. These activities were typical of most bird watching and observations (see below) were made along established tracks, at least 1 km from the nearest picnic or camping areas.

The least disturbed areas ('Undisturbed': UD) were situated away from all human activity, at least 500 m from the nearest track and more than 1 km from any picnic or camping areas.

Quantification of Bird Responses

The responses of birds to the activities typical of bird watching were assessed by describing the structure of bird communities and the reaction of specific species to experimental disturbances (measured as disturbance distance) in each of the three levels of disturbance. The quantification of these responses required the use of a variety of techniques, as described here.

Community Structure

The structure of avian communities was determined using two well-established bird censusing techniques: fix-width transects and point counts (Bibby, Burgess, Hill & Mustoe, 2000). These two techniques are recommended for reliable assessments of density and for efficient counts of species richness respectively (Bibby et al., 2000) and were used together in these surveys. Each transect was 100x20 m and was traversed at a slow pace with minimal disturbance to surrounding vegetation. Only species detected within the dimensions of the transect, including those passing through (below the base of the canopy) were recorded; birds detected above the canopy were ignored. At the completion of each transect, the observer paused motionless for 5 min before undertaking a point count (Bibby et al., 2000) over a 5 min period during which all species detected by eye or ear were identified. Throughout the point count a record of the direction and species associated with each stimulus was recorded on a circular sheet of paper as a means of minimising the possibility of double-counting (Bibby et al., 2000).

In general, the extensive experience of the observers was sufficient for most species to be identified reliably. However, where identification was difficult or impossible, sightings were recorded as 'unidentified'. At all times, a small cassette recorder was carried by the observer and used to record the vocalisations of unfamiliar species as a means of establishing identification at a later time. Three replicate transects – always more than 500m apart - were undertaken for each disturbance level at each site and the data combined for analyses.

Species-Specific Disturbance Distances

The disturbance and alert distance techniques employed were adapted previous studies (Cooke, 1980, Knight, 1984) especially those of Brumstein and associates (see Blumstein et al., 2003, Ikuta & Brumstein, 2003) and Fernández-Juricic and co-workers (Fernández-Juricic, 2000; Fernández-Juricic et al., 2001). In general, these techniques involved recording a series of distances before, during and following the approach of a human experimental intruder toward a previously undisturbed focal bird. Four measures of disturbance distance, adapted from Rollinson (2003) were recorded for each experimental interaction:

1. The distance (m) between the focal individual and the observer when bird was first detected
2. The distance (m) between the focal individual and the observer at the time of the bird's first reaction (the 'alert' distance)
3. The distance (m) the bird moved away following its first reaction
4. The total distance (m) moved by the focal individual away from the observer.

In addition, a number of behavioural variables were recorded but will not be included in the present report.

For inclusion in these experiments, birds had to be undisturbed (as indicated by behaviour) immediately prior to the commencement of the approach. Only single birds or those in very small (less than four) groups were used, and distance data only related to the individual focal animal.

Analyses

Comparisons of means were undertaken by either Student's T-tests or Analysis of Variance, for species richness, the numbers of individuals, and each of the disturbance distances. For community data, the three replicates were combined. For numbers of individuals only transect data was used in analyses while all species identified in both transects and point counts were used in comparisons of species richness.

Disturbance distances were log10(x+1) transformed for analysis to normalise their distributions. Analyses were initially undertaken only for species in which sufficient data (greater than 10 successful approaches) were available for at least two of the disturbance regimes. This enabled six species to be included from the rainforest data and only two from the eucalypt data sets. Two species (Eastern yellow robin and Lewin's honeyeater) were included in both rainforest and eucalypt comparisons.

As well as individual species analyses, a broader comparison of disturbance distances was undertaken using species combined into four classes based on general body size and primary foraging substrate. Body size of species was characterised as 'small' if less than 150 g and 'large' if greater than this weight. Foraging substrate was either 'ground' or 'non-ground'. This classification enabled the following numbers of species to be included in the analyses:

a) Large, non-ground species:	Rainforest: 5	Eucalypt: 8
b) Small, non-ground species:	Rainforest: 13	Eucalypt: 27
c) Large, ground species:	Rainforest: 5	Eucalypt: 2
d) Small, ground species:	Rainforest: 7	Eucalypt: 10

Chapter 3

Results

Influences on Community Parameters

Species Richness

A total of 57 species and 544 individual birds were recorded during the transects and point counts in all sites (Table 2). In general terms, more species were seen in eucalypt (47) than rainforest sites (34) while the number of individuals was the opposite of this trend (RF: 335 cf. Euc: 209).

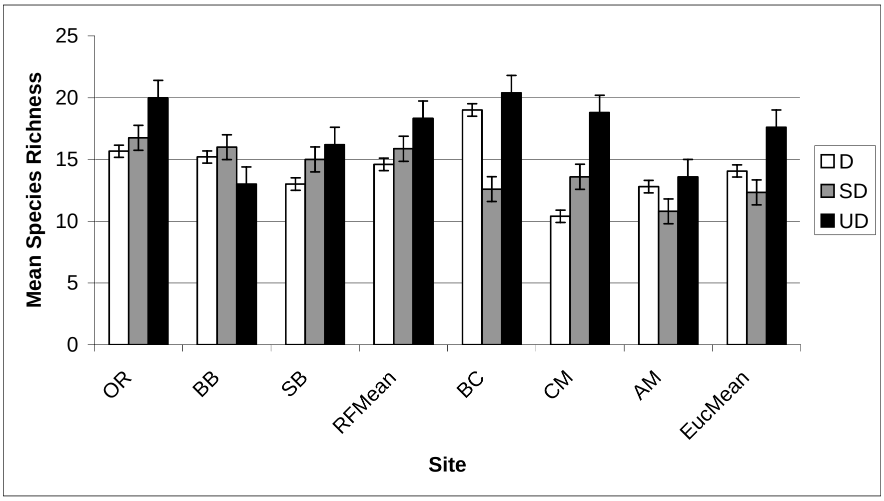
Table 2: Summary of species richness and numbers of individuals detected for each site

Habitat	Site	Species Richness			Number of individuals		
		D	SD	UD	D	SD	UD
RF	O'Reilly's	34	36	37	150	157	191
RF	Binna Burra	31	31	34	114	100	146
RF	Springbrook	33	34	35	87	109	118
Euc	Booloumba Creek	46	36	41	124	73	127
Euc	Moreland Park	36	41	47	95	90	117
Euc	Amamoor	32	40	47	77	88	128

(RF = rainforest sites; Euc = eucalypt sites) and disturbance type; (D=disturbed; SD=semi-disturbed; UD=undisturbed

Although the mean numbers of rainforest species varied considerably between sites (Figure 1), there were no significant differences between sites for each disturbance level. In contrast, the mean species richness of both disturbed and undisturbed sites was found to differ sightly but significantly between sites (F=4.58, p=0.03; F=5.47, p=0.02) (Figure 1). Nonetheless, data for all sites were combined for the overall comparisons of species richness for disturbance level.

Figure 1: Mean species richness for each site and levels of disturbance



(OR: O'Reilly's; BB: Binna Burra; SB: Springbrook; BC: Booloumba Ck; CM: C. Moreland Pk; D: disturbed; SD: semi-disturbed; UD: undisturbed)

The mean number of species identified in undisturbed sites was significantly greater than both semi-disturbed and disturbed sites in both rainforest and eucalypt areas (Table 3). In both habitat types, species richness did not differ between both semi-disturbed and undisturbed sites. (Unexpectedly, there was no difference in the mean number of species for disturbance level between habitat types as well).

Table 3: Comparison of mean species richness (transects and point counts combined)

Habitat	D	SD	UD	F	P
Rainforest	14.60±0.52	15.87±1.04	18.33±1.04	5.99	**0.005**
Eucalypt	14.07±1.22	12.33±1.01	17.60±1.23	5.35	**0.008**

Disturbed (D), semi-disturbed (SD) and undisturbed sites (UD) in rainforest and eucalypt sites (n=15 for each habitat type). ANOVA d.f = 2,42

Table 4 and Table 5 list species found in undisturbed sites only, disturbed sites only, or commonly in disturbance level for rainforest (Table 4) and eucalypt (Table 5) sites. Species listed as 'All sites' included only those with a minimum of 15 records and no fewer than four sightings in each disturbance level.

Table 4: Rainforest habitat bird species detected during transects and point counts

Disturbed sites only	Undisturbed sites only	All sites
Albert's lyrebird (1)	Blue-winged kookaburra (1)	Australian king parrot (7, 6, 6)
Pacific baza (1)	Emerald dove (1)	Black-face monarch(15,13,19)
Long-billed scrub-wren (1)	Red-browed treecreeper (1)	Brown gerygone (15, 26, 18)
Australian magpie (1)	Shining bronze-cuckoo (1)	Brown thornbill (18, 12, 31)
Mistletoebird (1)	Yellow-tailed black-cockatoo(1)	Crimson rosella(44, 29, 28)
Noisy friarbird (1)	White-eared monarch (1)	Eastern whipbird (5, 12, 15)
Scaly-breasted lorikeet (2)		East. yellow robin (19, 17, 13)
		Green catbird (22, 22, 27)
		Lewin's honeyeater (39, 40, 43)
		Logrunner (8, 7, 17)
		Pied currawong (14, 7, 4)
		Rufous fantail (8, 7, 17)

(a) only in undisturbed sites, (b) only in disturbed sites, and (c) consistently in disturbed, semi-disturbed and undisturbed sites. (Number in parentheses is number of individuals recorded for each habitat type)

For the rainforest sites, the largest group of species (12) were those found commonly in all disturbance levels. Surprisingly, many of these species were equally abundant in all disturbance levels. Lewin's honeyeater, for example, was found in similarly high numbers in all areas, and was the most frequently detected species in all but one site types in both rainforest and eucalypt areas. Only the crimson rosella, the second most abundant species in rainforest sites, was more common in the disturbed sites (a result related directly to the species' use of the well-known feeding station at O'Reilly's).

Table 5: Eucalyptus habitat bird species detected during transects and point counts

Disturbed sites only	Undisturbed sites only	All sites
Black-chinned honeyeater (2)	Pacific baza (1)	Noisy miner (9, 8, 20)
Dollarbird (1)	Fan-tailed cuckoo (2)	Black-faced cuckoo-shrike (3, 6, 7)
Grey butcherbird (3)	Pallid cuckoo (1)	Brown cuckoo-dove (14, 15, 17)
Logrunner (1)	Rainbow lorikeet (3)	Crimson rosella (6, 2, 8)
Australian magpie (11)	Red-browed finch (3)	East. Yellow robin (5, 9, 14)
Peaceful dove (1)	Rose robin (1)	Grey shrike-thrush (13, 3, 18)
Rainbow beeeater (2)	Shining bronze-cuckoo(1)	Laughing kookaburra (11, 7, 5)
Red-browed treecreeper (2)	Sitella (8)	Lewin's honeyeater (24, 24, 16)
Restless flycatcher (2)	Yellow-rumped thornbill (3)	Pied currawong (9, 8, 10)
Satin flycatcher (1)		Sulphur-crested cockatoo (13, 11, 4)
Variegated fairy-wren (4)		
Woopoo fruit-dove (6)		
White-throated gerygone (1)		
White-winged triller (8)		

(a) Only in undisturbed sites, (b) only in disturbed sites, and (c) consistently in disturbed, semi-disturbed and undisturbed sites. (Number in parentheses is number of individuals recorded fir each habitat type)

Compared to these highly tolerant species, the seven species found only in the undisturbed rainforest sites were all detected as single individuals only (Table 4). Similarly, the seven species found only in the open disturbed areas were also found in small numbers.

In contrast to the rainforest sites, the largest group of species associated with eucalypts sites were the 14 species found only in the disturbed sites (Table 5). Again, most of these were found in relatively small numbers (the only exceptions being Australian magpies and white-winged trillers). Nine species were found (again, in mainly low numbers) only in undisturbed sites, while a further 10 species are found equally often in all disturbance levels. The two most abundant of these highly tolerant species were the Lewin's honeyeater (see above) and brown cuckoo-dove.

Numbers of Individuals

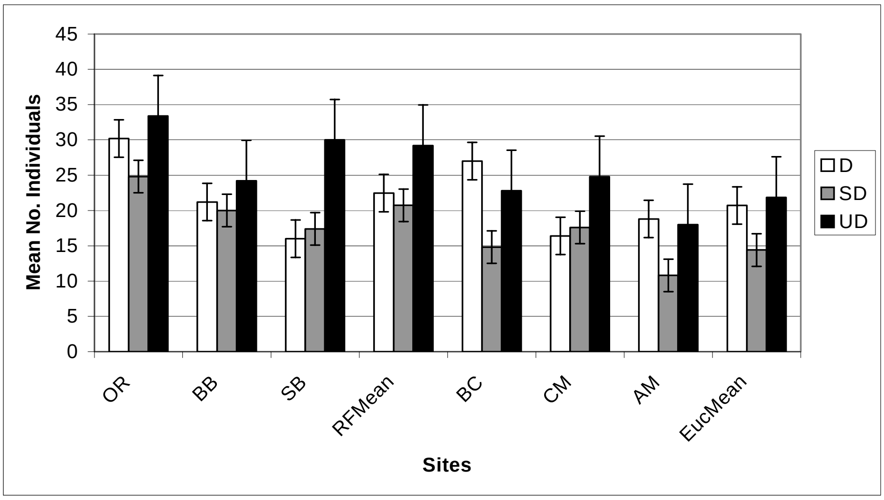
The differences in the numbers of species detected in site of differing disturbance levels were less clear than the results for species richness (Figure 2, Table 6); the only significant difference was the number of birds found in undisturbed rainforest sites.

Table 6: Comparison of mean number of individuals detected

Habitat	D	SD	UD	F	P
Rainforest	22.47±2.22	20.73±2.16	29.20±2.50	3.75	0.032
Eucalypt	20.7±2.38	14.4±1.69	21.86±2.82	2.93	0.064

Disturbed (D), semi-disturbed (SD) and undisturbed sites (UD) in rainforest and eucalypt sites (n=15 for each habitat type). ANOVA d.f = 2,42

Figure 2: Mean number of individuals (all species included) for each site and levels of disturbance



(OR: O'Reilly's; BB: Binna Burra; SB: Springbrook; BC: Booloumba Ck; CM: C. Moreland Pk; D: disturbed; SD: semi-disturbed; UD: undisturbed)

Disturbance Distances

A total of 34 species in rainforest sites and 45 species in eucalypt sites (excluding all unable to be identified) were used in 335 and 209 experimental approaches respectively. However, only species for which a minimum of 20 approaches were successfully completed were included in the analyses of individual species (see below). The remainder of species were combined into four categories based on size and primary foraging substrate (as described in Methods above).

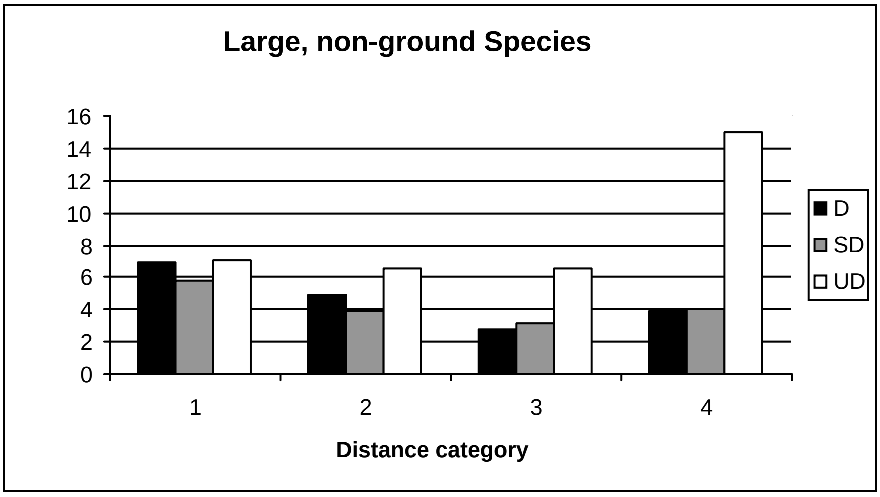
Species Categories

To add clarity, only comparisons in which significant differences were found are presented here and only rainforest site data are illustrated.

Large, Non-Ground Species

For rainforest species, this category included five species and a total of 29 approaches. There were no differences in the first three mean disturbance distances for any disturbance level but distance 4 (the distance the bird moved away from the intruder) was very significantly longer in the undisturbed sites (Figure 3). There were no differences in the mean distances obtained for eucalypt species (using eight species and 29 approaches).

Figure 3: Mean disturbance distance (m) for large, non-ground species



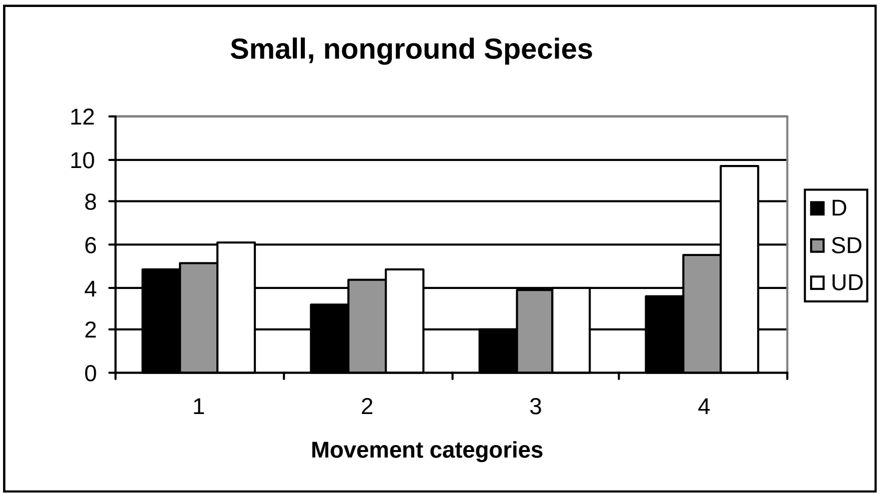
(5 species, 29 approaches) (D: disturbed; SD: semi-disturbed; UD: undisturbed)

Small, Non-Ground Species

This category contained by far the largest number of samples with 13 species and 145 approaches for rainforest species and 27 species and 135 approaches for eucalypt species. For rainforest species (Figure 4), the comparison of the four mean disturbance distances found a significant difference for all disturbance level (1: F=3.32, p=0.04; 2: F=6.62, p=0.002; 3: F=12.33, p=0.0001; 4: F=17.30, p=0.0001). In general, distance 4 was again much greater in the undisturbed sites.

For eucalypt species, the results were similarly strong (1: F=7.75, p=0.001; 2: F=14.01, p=0.0001; 3: F=19.45, p=0.0001) except for distance 4 which were non-significant (F=2.39, p=0.09).

Figure 4: Mean disturbance distance (m) for small, non-ground species

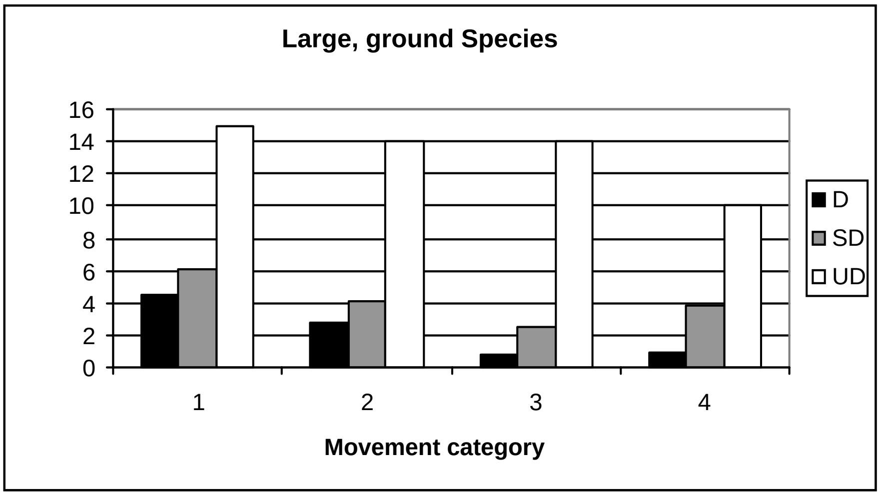


(13 species, 145 approaches) (D: disturbed; SD: semi-disturbed; UD: undisturbed)

Large, Ground Species

This category contained the smallest data set and is based on five species and 42 approaches for rainforest and only two species and 11 approaches for eucalypt species. Notwithstanding this small sample size, all comparisons by disturbance level found very significant differences in all mean disturbance distances (Figure 5). In every case, the mean disturbance distance in the undisturbed areas was more than twice that of the other two levels.

Figure 5: Mean disturbance distance (m) for large, ground species



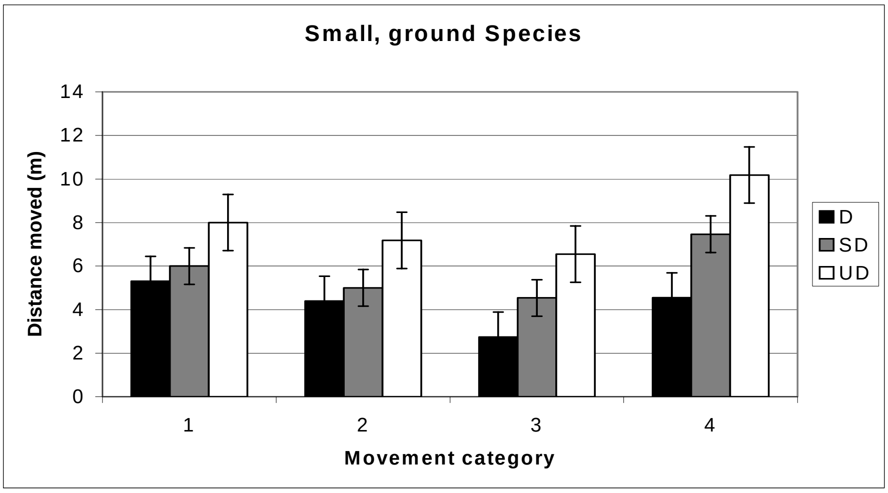
(5 species, 42 approaches) (D: disturbed; SD: semi-disturbed; UD: undisturbed)

Despite the paucity of data from eucalypt species, highly significant differences were found for distances 2 (F=15.46, p=0.003) and 3 (F=12.74, p=0.006).

Small, Ground Species

This category was based on seven species and 45 approaches for rainforest and 10 species and 26 approaches for eucalypt species. All but distance 1 were found to be significantly different for rainforest species (Figure 6) (1: F=2.66, p=0.08; 2: F=5.56, p=0.007; 3: F=8.84, p=0.001; 4: F=5.07, p=0.011). None of the disturbance distance comparisons were significant for eucalypt species, however.

Figure 6: Mean disturbance distance (+s.e) (m) for small, ground species



(7 species, 45 approaches) (D: disturbed; SD: semi-disturbed; UD: undisturbed)

Individual Species

We obtained sufficient data from six rainforest species and two eucalypt species is enable detailed comparisons of mean disturbance distances for the three disturbance distances.

Rainforest Species

Australian brush-turkey

Although an extremely abundant species in rainforest areas, we were only able to obtain disturbance distance data from disturbed and semi-disturbed sites (Table 7). The comparisons found marginally significant differences in the first tree distance measures but not in distance 4.

Table 7: Comparison of mean disturbance distances for Australian brush-turkeys in rainforests

Category	D	SD	UD	F	P
Dist 1	4.43±0.52	6.08±2.10	-	2.38	**0.050**
Dist 2	2.62±0.32	3.85±0.56	-	2.04	**0.049**
Dist 3	0.72±0.01	1.95±0.63	-	2.46	**0.019**
Dist 4	1.02±0.25	2.48±0.96	-	1.77	0.084

(Dist 1 = Distance (m) bird first sighted, Dist 2 = Distance (m) bird first reacts, Dist 3 = Distance (m) at which bird moves, Dist 4 = Distance (m) bird moved away from observer; D = disturbed sites (n=21), SD = semi-disturbed sites (n=13), UD = undisturbed sites). ANOVA d.f.=2,23

Logrunner

Significant differences were found for distances 1 and 3 in which the mean disturbance distance for birds in undisturbed areas was greater than in both of the other levels (Table 8).

Table 8: Comparison of mean disturbance distances for logrunners in rainforests

Category	D	SD	UD	F	P
Dist 1	5.71±0.81	5.19±0.57	10.00±2.52	4.51	**0.021**
Dist 2	5.00±0.65	4.47±0.46	8.33±0.88	5.56	**0.01**
Dist 3	3.71±0.75	3.92±0.40	8.00±1.00	7.433	**0.003**
Dist 4	5.71±1.32	7.61±1.03	13.33±4.41	2.975	0.069

(Dist 1 = Distance (m) bird first sighted, Dist 2 = Distance (m) bird first reacts, Dist 3 = Distance (m) at which bird moves, Dist 4 = Distance (m) bird moved away from observer; D = disturbed sites (n=7), SD = semi-disturbed sites (n=18), UD = undisturbed sites (n=3)). ANOVA d.f.=2,25

Yellow-throated scrub-wren

The mean disturbance distance of birds in undisturbed sites was significantly greater than that from semi-disturbed and disturbed sites (Table 9).

Table 9: Comparison of mean disturbance distances for yellow-throated scrub-wrens in rainforests

Category	D	SD	UD	F	P
Dist 1	3.60±0.51	5.55±0.61	7.22±0.94	4.33	**0.026**
Dist 2	3.00±0.32	4.91±0.48	7.00±1.00	6.02	**0.008**
Dist 3	2.10±0.64	4.18±0.40	6.22±0.88	7.65	**0.003**
Dist 4	3.50±1.05	6.27±0.84	9.56±0.94	8.40	**0.002**

(Dist 1 = Distance (m) bird first sighted, Dist 2 = Distance (m) bird first reacts, Dist 3 = Distance (m) at which bird moves, Dist 4 = Distance (m) bird moved away from observer; D = disturbed sites (n=5), SD = semi-disturbed sites (n=11), UD = undisturbed sites (n=9)). ANOVA d.f.=2,22

White-browed scrub-wren

Mean disturbance distances 2, 3 and 4 were all significantly different for sites, with the distance of undisturbed birds being greater (Table 10).

Table 10: Comparison of mean disturbance distances for white-browed scrub-wrens in rainforests

Category	D	SD	UD	F	P
Dist 1	4.08±0.42	4.53±0.34	5.58±0.47	2.69	0.078
Dist 2	3.17±0.27	3.79±0.29	4.67±0.40	3.67	**0.033**
Dist 3	2.21±0.27	3.30±0.41	4.08±0.36	3.54	**0.037**
Dist 4	2.75±0.46	3.72±0.56	10.08±1.01	26.15	**0.0001**

(Dist 1 = Distance (m) bird first sighted, Dist 2 = Distance (m) bird first reacts, Dist 3 = Distance (m) at which bird moves, Dist 4 = Distance (m) bird moved away from observer; D = disturbed sites (n=12), SD = semi-disturbed sites (n=27), UD = undisturbed sites (n=12)). ANOVA d.f.=2,48

Lewin's honeyeater

In contrast to all other species, none of the disturbance distances of this species differed between disturbance levels (Table 11).

Table 11: Comparison of mean disturbance distances for Lewin's honeyeater in rainforests

Category	D	SD	UD	F	P
Dist 1	5.00±1.08	4.80±0.86	6.40±0.93	0.88	0.439
Dist 2	3.75±1.11	2.80±1.79	5.20±2.17	1.73	0.222
Dist 3	2.25±0.95	2.80±0.80	4.60±1.17	1.52	0.259
Dist 4	4.55±2.37	5.50±5.59	13.40±4.31	2.19	0.158

(Dist 1 = Distance (m) bird first sighted, Dist 2 = Distance (m) bird first reacts, Dist 3 = Distance (m) at which bird moves, Dist 4 = Distance (m) bird moved away from observer; D = disturbed sites (n=4), SD = semi-disturbed sites (n=5), UD = undisturbed sites (n=5)). ANOVA d.f.=2,11

Eastern yellow robin

All disturbance distances measured in undisturbed sites were highly significantly different to those measured in both of the other disturbance levels (Table 12).

Table 12: Comparison of mean disturbance distances for eastern yellow robins in rainforests

Category	D	SD	UD	F	P
Dist 1	4.01±0.61	4.68±0.34	7.88±1.14	8.71	**0.001**
Dist 2	3.29±0.45	3.86±0.32	6.88±0.97	10.52	**0.0001**
Dist 3	1.82±0.22	3.36±0.32	5.75±0.80	17.65	**0.0001**
Dist 4	4.71±0.99	5.20±0.85	11.50±0.93	9.92	**0.0001**

(Dist 1 = Distance (m) bird first sighted, Dist 2 = Distance (m) bird first reacts, Dist 3 = Distance (m) at which bird moves, Dist 4 = Distance (m) bird moved away from observer; D = disturbed sites (n=14), SD = semi-disturbed sites (n=22), UD = undisturbed sites (n=8)). ANOVA d.f.=2,41

Eucalypt Species

Lewin's honeyeater

Only two of the disturbance distances (3 and 4) of this species differed significantly between disturbance levels (Table 13).

Table 13: Comparison of mean disturbance distances for Lewin's honeyeaters in eucalypts

Category	D	SD	UD	F	P
Dist 1	5.40±0.81	8.36±1.06	9.67±1.45	2.27	0.135
Dist 2	4.20±0.73	6.55±0.76	7.67±1.45	2.56	0.108
Dist 3	2.30±0.92	6.36±0.74	7.33±1.45	6.17	**0.010**
Dist 4	5.00±1.92	9.73±1.05	5.00±0.00	4.264	**0.033**

(Dist 1 = Distance (m) bird first sighted, Dist 2 = Distance (m) bird first reacts, Dist 3 = Distance (m) at which bird moves, Dist 4 = Distance (m) bird moved away from observer; D = disturbed sites (n=5), SD = semi-disturbed sites (n=11), UD = undisturbed sites (n=3)). ANOVA d.f.=2,16.

Eastern yellow robin

Disturbance distances 2, 3 and 4 measured in undisturbed sites were significantly different to those measured in both of the other disturbance levels (Table 14).

Table 14: Comparison of mean disturbance distances for eastern yellow robins in eucalypts

Category	D	SD	UD	F	P
Dist 1	7.00±1.72	6.90±0.69	8.40±0.65	0.61	0.551
Dist 2	4.11±0.45	5.30±0.86	7.10±0.43	5.75	**0.009**
Dist 3	2.89±0.35	4.60±0.90	6.70±1.64	8.55	**0.001**
Dist 4	5.72±1.03	8.80±0.90	10.40±1.18	5.03	**0.014**

(Dist 1 = Distance (m) bird first sighted, Dist 2 = Distance (m) bird first reacts, Dist 3 = Distance (m) at which bird moves, Dist 4 = Distance (m) bird moved away from observer; D = disturbed sites (n=9), SD = semi-disturbed sites (n=10), UD = undisturbed sites (n=10)). ANOVA d.f.=2,26.

Chapter 4

Discussion

This study, which counted 544 individual birds of 57 species of bird, and performed 544 experimental approaches of 34 species of birds, was one of the most comprehensive studies of the impacts of human activities on bird communities so far conducted. To date, virtually all similar studies have focussed on either specific species (e.g. Knight, 1984; Giese, 1998; Liley & Clarke, 2003) or particular guilds or taxonomic groups (e.g. Holmes et al*.,* 1993; Richardson & Miller, 1997; Carney & Sydeman, 1999). Community-based or multispecies studies (e.g. Burger & Gochfeld, 1990; Blumstein et al*.,* 2003; Ikuta & Blumstein, 2003) are relatively rare in this field.

The design of this study enabled the structure of avian communities and the immediate reactions of selected individual species living in sites experiencing differing levels of human disturbance to be compared. For the primary purpose of this study, it was the intermediate disturbance level, 'semi-disturbed', which most closely resembled the activities of bird-watchers. In contrast, 'disturbed' locations were associated with far greater levels of visitor density, people-generated noise, and the food-attraction features of picnics and barbeques. 'Undisturbed' locations were true controls in being permanently devoid of all forms of human intrusion (apart from the observers). Therefore, a key comparison of interest to this study was whether the information obtained from semi-disturbed areas more closely resembled that of the far more heavily used disturbed areas or the pristine undisturbed areas. In other words, was human disturbance per se a significant influence on bird communities?

Given the 'natural experiment' nature of the study sites (see Bibby et al., 2000), it must be acknowledged that the forms of human disturbance could not be controlled and inevitable differences occurred between sites of ostensibly the same level of disturbance. For example, although each of the disturbed rainforest sites were located in very similar natural environments, one (O'Reilly's) differed from the others in having a well-established feeding station, attracting large numbers of crimson rosellas, king parrots, Australian brush-turkeys and numerous others. Obviously, the extent to which certain species are attracted to such a significant food source is likely to have altered the composition of the community in this site.

In the discussion that follows, the main emphasise will be on discerning key patterns among the large number of analyses. Generally, individual species will only be considered in detail where the results are of particular importance. In addition, there are few valid reasons for comparing cross-habitat results; suffice to say, in most of the surveys conducted here, eucalypt sites supported higher numbers of species than did rainforest sites.

Impact of Long-Term Disturbance on Species Richness

The results of the comparison of species richness along the different levels of disturbance were remarkably clear in both habitat types: undisturbed sites supported significantly larger numbers of species than either semi-disturbed or undisturbed sites. Interestingly, this was only partially related to the number of species that were found only in the undisturbed sites. Table 4 and Table 5 reveal that while a total of 15 (rainforest and eucalypt combined) species were found only in undisturbed sites, the largest component of the species found in these remote sites were 22 highly abundant species birds found relatively equally in sites of all disturbance levels.

This was an unexpected result. Certainly, we anticipated identifying numerous species that exhibited minimal tolerance to all levels of human disturbance. The lists of these 'intolerant' species (Table 4 and Table 5) show a majority to be smaller passerines, many of which may be regarded as specialists. Notably, the list includes three cuckoo species (fan-tailed cuckoo, pallid cuckoo and shining bronze-cuckoo), a group known to be declining globally (Davies, 2000) and nationally (Veerman, 2002). Another species, the rose robin, has previously been classified as intolerant of development in southeast Queensland (Sewell & Catterall, 1998).

It was, however, the large number of relatively common species found at similarly high numbers in sites at each disturbance site that is of particular interest. Although some of these species were clearly more abundant in the disturbed sites due to the attraction of anthropogenic food resources (most obviously crimson rosella, pied currawong, and laughing kookaburra), most were not (Table 4 and Table 5). Indeed, possible the most unexpected result was the extent to which some species (e.g. Lewin's honeyeater, green catbird, black-faced monarch) appeared apparently unaffected by the difference in disturbance level, occurring at almost identical numbers at each level. Lewin's honeyeater is especially noteworthy, being among the most abundant species in all disturbance levels in both rainforest and eucalypt sites.

Most of the species found only in either undisturbed or disturbed sites were, in comparison to these far more abundant species, only rarely encountered. The main exceptions to this were flocking species such as varied sitellas or white-winged trillers (Table 5), and especially the large number of Australian magpies utilising the extensive areas of lawn typically of the picnic grounds used for disturbed sites. This latter species is typical of a number of non-forest species that had successfully occupied the human-dominated landscape of the disturbed sites, rather than a forest-associated species only visiting the area temporarily. Typical of the open-habitat species encountered were dollarbirds, rainbow bee-eaters, restless flycatchers, peaceful doves and, of course, magpies. None of these species would normally be found in the forest habitat characteristic of the location. We estimate that at least six of the 21 species found only in the disturbed habitats were species typical of much more open habitats.

Unfortunately, it is not possible to determine whether the presence of any of the species found only in the disturbed sites were present because they had been attracted to the area by the activities of humans. Even the presence of the Australian magpie, although well-known as a scavenger at picnic grounds, is fundamentally associated with open lawned areas rather than the anthropogenic food sources per se (Jones, 2002).

Impact of Long-Term Disturbance on Numbers of Individuals

The comparison of the mean numbers of individuals showed a similar pattern to that of the species richness data: undisturbed sites supported significantly larger numbers of birds than either semi-disturbed or disturbed sites. This was only evident, however, in the rainforest sites; there was no difference in the mean numbers of individuals for eucalypt sites. While it may be tempting to interpret these results as indicating that disturbances lead naturally to fewer birds as well as fewer species, this result is actually the opposite to what was expected. A large number of studies, especially those comparing the avifaunas of urban areas with undeveloped areas, commonly report far greater numbers of birds (though often with lower species diversity) in the most disturbed areas (see, for example, Sewell & Catterall, 1998; Marzluff, 2001). This is typically due to the presence of large numbers of a few species, especially several ubiquitous introduced birds (Blair, 2001) as well as certain native species whose presence is often related to the absence of many smaller species (Marzluff, 2001). The large numbers of these synanthropic species is normally associated with their successful appropriation of anthropogenic resources, especially food (Emlen, 1974; Marzluff, McGowan, Donnelly & Knight, 2001).

Each of the disturbed sites were frequently-used picnic areas (and, in one case, a famous bird feeding station), attracting considerable numbers of birds long-familiar with utilising these regular sources of food. Thus, it is surprising that even the presence of such species in large numbers did not result in higher numbers in the disturbed sites. As mentioned above, this result seems to be related to the unexpectedly high number of several species that were equally abundant in all disturbance types.

Impact of Long-Term Disturbance on the Disturbance Distance of Species

The use of disturbance distances (also known as 'flight initiation distance' (Blumstein et al., 2003), 'flush distance' (Richardson & Miller, 1997), or 'escape flight distance' (Madsen & Fox, 1995)) as a means of quantifying the responses of animals to the approach of humans is now well established. Nonetheless, its apparent simplicity of application has lead to some inappropriate use and invalid interpretation of results (see Knight & Cole, 1995). In this study we have attempted to overcome these methodological problems by replication, confining our experimental approaches to birds in forested habitats (thereby negating the important issue of the distance to refuge; Dill & Houtman, 1989), and the use of four measures of disturbance distance (as devised by Rollinson, 2003). The latter three of these metrics (distances 2, 3 and 4) effectively measure increasingly significant components of an animals fleeing activity, while the first (distance 1) is mainly an indication of the 'background' to all other responses. Although all four distances are reported here, the most pertinent will tend to be distance 4, the total distance moved by a focal bird in response to an approach.

It should also be pointed out here that these metrics also provide a very valuable assessment of the extent to which birds have become habituated to the presence of humans. Habituation refers to the waning of a response to a human disturbance by an animal (Knight & Temple, 1995) and it has been suggested as being an essential behaviour response for animals living with some level of human disturbance (Rollinson, 2003). Thus, it would be expected that birds living in areas experiencing the greatest level of human activity (here, the disturbed sites) should be the most habituated, while those in the undisturbed sites should be entirely non-habituated. Logically, birds living in the semi-disturbed areas should be intermediate between the two. Again, given that this research is focussed primarily on bird watching impacts, the key comparison will be whether the disturbance distances recorded for birds in semi-disturbed sites is more similar to those living in undisturbed or disturbed sites.

The first group of analyses were performed on four loose groups of species, classified generally on the basis of body size and main foraging substrate. As these groups contained greatly varying numbers of species and approaches, the significance of the results must be weighed cautiously. Note also that the 'small-sized, tree-foraging' groups contained by far the largest data set, while the large-sized, ground-foraging' groups contained the least data. Nonetheless, the general results were relatively obvious.

First, there was extremely clear evidence of an effect of disturbance level on disturbance distance in most comparisons, with the mean disturbance distances being significantly larger in undisturbed sites and smallest in disturbed sites. These results were most obvious in the data rainforest sites where 12 of the 16 (four distances x four species groups) ANOVAs produced highly significant results. Only the 'large, non-ground' group was less than overwhelming, with only distance 4 showing a significant difference.

The results for the eucalypt sites was generally similar but far less dramatic with only two of the groups ('small, non-ground' and 'large, ground') producing significant differences between mean disturbance distances for different levels of disturbance, and none showing a difference for distance 4.

This apparent contrast between habitat types is somewhat intriguing. Finding that mean disturbance distances between birds living at different levels of disturbance were not statistically different (as was the case in 11 of the 16 comparisons for eucalypt sites) from birds living permanently away from humans suggests strongly that the species involved had not habituated to any significant extent. This is especially striking because of the far more definite results from the rainforest sites, and infers that the process that could eventually lead to habituation may be more pronounced in the rainforest sites. We are unable to assess this suggestion to any depth here, beyond noting that, although all of sites did receive large numbers of visitors, the activities engaged in may be quite different between habitats. For example, the predominant reason for visiting each of the rainforest locations is overwhelmingly for day-visits, often involving picnicking, and all sites are well attended even on weekdays. In contrast, the main recreational activity associated with the eucalypt sites was weekend family camping in a bush setting. It is possible that the birds resident in these areas have responded very differently to these stimuli.

The analyses of disturbance distances for the five species selected for individual assessment generally reflect very similar results to those described above: in general, those birds living in undisturbed sites had significantly greater disturbance distances than those living in either semi-disturbed or disturbed sites. The primary exceptions to this pattern were the results for Lewin's honeyeater, one of the most abundant species in all sites and disturbance distances. In contrast to all other species, there were no differences in most disturbance distance for this species in both habitat types (only distances 3 and 4 in eucalypt sites proved to be significantly different).

In summary, most of the multi-species groups and individual species examined in these analyses exhibited clear differences in mean disturbance distances between those measured in undisturbed areas compared to those in semi-disturbed and disturbed areas. Moreover, in most of these comparisons, there was no statistical difference between the two latter levels of human disturbance. These results were, however, unequivocal only in the rainforest sites; in the eucalypt sites the majority of comparisons failed to confirm a difference.

Conclusion

Almost every aspect of this comprehensive study confirmed that birds were significantly influenced by the activities of humans; compared to those living in completely undisturbed locations, birds living in locations experiencing both high or moderate levels of disturbance were characterised by significantly: lower species richness; lower numbers of individuals; and greater disturbance distances. Importantly, according to the various variables measured here, there appeared to be virtually no difference between the two levels of disturbance as employed in this design. This would seem to indicate that birds respond similarly to a range of human activities.

These results provide further confirmation that even apparently benign activities such as bird watching can have a marked effect on bird populations (Wearing & Neil, 1999). They also add general support to observations that birds will avoid humans if possible (Burger, Gochfeld & Niles, 1995; Burger & Gochfeld, 1998) and prefer undisturbed over disturbed habitats (Hockin et al., 1992). However, further studies will be necessary to determine whether such activities actually impact on the reproductive outcomes and ultimately the long-term survival of species in areas so affected.

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