A STATISTICAL ANALYSIS OF TRENDS IN DETECTION RATES OF WOODLAND BIRDS IN THE ACT, 1998 TO 2004.

Prepared for Canberra Ornithologists Group (COG) and Environment ACT

by

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1. HISTORY OF PROJECT

Much of the native woodland vegetation in south-eastern Australia has been cleared or substantially modified since European settlement. Recent mapping has estimated that 45% of the ACT and NSW Southern Tablelands region supported grassy ecosystems pre-1750, and that this had been reduced to 13% cover by 2000 (Fallding 2002). Two thirds of this remaining native vegetation is box-gum grassy woodland.

Yellow Box-Red Gum *Eucalyptus melliodora-E.blakelyi* Grassy Woodland has been declared an endangered ecological community in the ACT. This community (and other lowland woodland) supports 10 bird species that are listed as threatened in the ACT or NSW, and many other bird species that appear to be declining. About one third of the threatened community in the ACT is protected in nature reserves. Some of the rest has various degrees of protection under other Territory Plan land use categories and as Designated Areas under the National Capital Plan, and a small amount is under urban use. The remaining third is on land identified as Broadacre Rural or Plantation Forestry land (ACT Government 2004). Management methods (grazing, weed control, fire hazard reduction) differ for these land use categories, and this affects the type, quality and regeneration of bird habitats.

One of the goals of the ACT Lowland Woodland Conservation Strategy (ACT Government 2004) is to 'Conserve in perpetuity, viable, wild populations of all Lowland Woodland flora and fauna species in the ACT and support regional and national efforts towards conservation of these species'. Some of the Key Actions identified in this report relate to threatened and declining woodland birds, and the need for more information on their distribution, abundance, ecology and conservation requirements.

In 1998-99, Environment ACT made the first of a series of grants to COG to carry out monitoring of bird species and numbers at lowland grassy woodland sites in the ACT. A working group, including COG members and professionals working in wildlife research, designed the survey.

With continuing support from Environment ACT, quarterly surveys were being carried out at 128 monitoring sites in 13 areas by 2005 (Table 1 and Map 1). A habitat assessment was carried out for each monitoring site, describing the structure of the vegetation and other habitat features (see Form A attached).

COG received funding for the analysis by Ross Cunningham of Statwise Pty Ltd of data collected up to 2001. This work compared the abundance of birds in reserve and leasehold areas, and included detailed analysis of records for 10 woodland bird species (Cunningham 2003). A progress report for the project was prepared using data collected between 2001 and 2003, with discussion of threatened species records and preliminary habitat descriptions for some species (Rowell 2004).

Since the previous reports of this survey, new sites have been added to the project at Goorooyarroo Reserve in Gungahlin, Kama in Belconnen and in the Naas Valley. This gives good coverage of grassy woodlands in the ACT, both geographically and in the range of woodland quality and tenure types (see Map 1). The northern woodlands which extend almost uninterrupted from Hall to Newline Quarry will now be well-surveyed, and comparisons will be possible of bird populations and habitats across several different management regimes.

Several other recommendations arising out of the previous reports have been implemented. These include:

- continuing the surveys with the methods as modified in 2003
- restarting Majura Field Firing Range surveys in 2005
- replacing Lambrigg with new Naas site (in spring 2005)
- surveys carried out over two days if necessary, in order to survey early in the day
- production of habitat database for use in longitudinal analysis of bird detection trends against habitat data.

2. METHODS

For this report, Ross Cunningham has undertaken a statistical analysis of data on 63 species in the Woodland data set that appear in more than 1% of the 147 surveys undertaken at 132 sites in 13 areas between September 1998 and June 2004. He has produced longitudinal profiles of the probability of detection for these species and has also assessed whether profiles differed between land tenure classes and classes of a selection of habitat variables. The association between habitat variables and tenure was also assessed.

The smoothed trend was determined using a regression spline, the seasonal component by a second order harmonic, and the 'linear' trend by fitting a straight line (see sample graph below). The scale for analysis was logistic and so the linear line on the natural scale will be slightly curved. Statistical adjustments have been made to correct for the lack of balance in the data set, due to the changing numbers of sites being surveyed during the period. The contribution that each survey area has made to the data set is shown in Table 2. The model is a special case of a general statistical framework for analysis known as generalized linear mixed models (GLMM).

Graphs of temporal trends in detection rates for species which occur in more than 1% of surveys are attached at the end of this report.

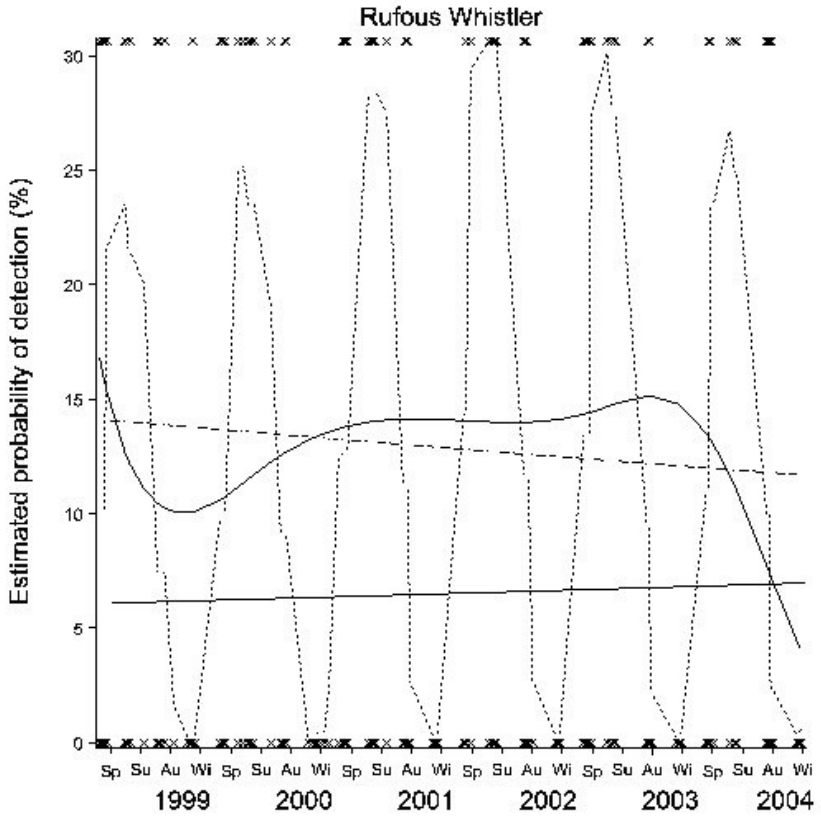


Table 1: Site tenure and history of survey

Site	Tenure	First surveyed	Comments
Mulligan's Flat (MUL)	Nature reserve	1996	Survey methodology changed in 1998 to match COG Woodland Bird survey. 24 sites, not all woodland.
Majura Field Firing Range (MJF)	Defence land	spring 1998-Dec 2000, restarted June 2005	Break in surveys due to problems with access. 10 sites, not all woodland, reduced to 8 sites in 2005.
Castle Hill (CAS)	Rural lease	Sept 1998	Grazed by sheep. Extra surveys Feb, Apr, Oct 2000.
Gooroo (GOO)	Rural lease, became Nature Reserve in early 2004	Sept 1998	Pasture improvement at some sites.
Mt Majura (MAJ)	Nature reserve and buffer between houses and reserve	Sept 1998	North-western end of Mt Ainslie-Mt Majura Reserve.
Red Hill (RED)	Nature reserve	Sept 1998	8 sites burnt or part-burnt, light to moderate burns, December 2001. Extra habitat surveys in March, June 2002.
Symonston (SYM)	Rural lease, Nature Reserve, hills/ridge/buffer	Sept 1998	Sites 1-9 grazed. Sites 7-9 surveyed first year only, replaced by 10-12 (East O'Malley) Sep 2000. 10-12 lost to housing, replaced by 13-15 in new NR in June 2004.
Hall/Gold Ck (HAL)	Rural lease	June 2000	Lightly grazed.
Newline Quarry(NLN)	Rural agistment	July 2000	Grazed by sheep, cattle. Some pasture improvement.
Tuggeranong Hill (TUG)	Nature reserve, hills/ridge/buffer	Sept 2000	Preliminary bird survey in Aug 2000. Sites 8 and 9 cleared for housing between June and Sep 2001 surveys, not replaced.
Lambrigg (LAM)	Rural lease	Dec 2001-Mar 2003	Sites 1, 2, and 9 withdrawn after Dec 2001 survey. New sites 10-12 first surveyed in Mar 2003. All sites (3-8, 10-12) burnt (moderate to hot burn) in Jan 2003. All sites withdrawn after Mar 2003 survey.
Campbell Park (CMP)	Nature Park and Defence land	June 2003	Sites 1 & 2 occasionally grazed in past.
Gooroo South (GOS)	Rural leases, became Nature Reserve in early 2004	April 2004	Overgrazed in places, especially the southern part, and drought affected when it became reserve. Problem weed areas, e.g. serrated tussock, thistle (J Bounds pers. comm.).
Naas (NAS)	Rural lease bordering Namadgi NP	June 2005	6 sites only. Grazing levels vary across lease. Several sites burnt in January 2003 bushfires.
Kama (KAA)	Resumed rural lease, under agistment	Oct 2005	Pasture improved paddock and large unimproved paddock in Molonglo Valley

Table 2. History of Woodland Bird Survey, showing contribution of each survey area to data set.

Season of survey	Year	Number of sites surveyed in each area												
		CAS	CMP	GOO	GOS	HAL	LAM	MAJ	MJF	MUL	NLN	RED	SYM	TUG
Spr	1998	9	-	9	-	-	-	9	10	24	-	9	9	-
Sum	1998	9	-	9	-	-	-	9	10	24	-	9	9	-
Aut	1999	9	-	9	-	-	-	9	10	24	-	9	9	-
Win	1999	9	-	9	-	-	-	9	-	24	-	9	9	-
Spr	1999	9	-	9	-	-	-	9	-	24	-	9	9	-
Sum	1999	9	-	9	-	-	-	9	10	24	-	9	9	-
Aut	2000	9	-	9	-	-	-	9	10	24	-	9	9	-
Win	2000	9	-	9	-	9	-	9	10	24	9	9	9	-
Spr	2000	9	-	9	-	9	-	9	10	24	9	9	9	9
Sum	2000	9	-	9	-	9	-	9	10	24	9	9	9	9
Aut	2001	9	-	9	-	9	-	9	-	24	9	9	9	9
Win	2001	9	-	9	-	9	-	9	-	24	9	9	9	9
Spr	2001	9	-	9	-	9	-	9	-	24	9	9	9	7
Sum	2001	9	-	9	-	9	9	9	-	24	9	9	9	7
Aut	2002	9	-	9	-	9	9	-	-	24	9	9	9	7
Win	2002	9	-	9	-	9	9	9	-	24	9	9	9	7
Spr	2002	9	-	9	-	9	9	9	-	24	9	9	9	7
Sum	2002	9	-	9	-	9	9	9	-	24	9	9	9	7
Aut	2003	9	-	9	-	9	9	9	-	24	9	9	9	7
Win	2003	9	9	9	-	9	-	9	-	24	9	9	9	7
Spr	2003	9	9	9	-	9	-	9	-	24	9	9	9	7
Sum	2003	9	-	9	-	9	-	9	-	24	9	9	9	7
Aut	2004	9	9	9	-	9	-	9	-	24	9	9	7	7
Win	2004	9	9	9	9	9	-	9	-	24	9	9	9	7

3. RESULTS AND COMMENTS

Of the 63 most commonly recorded species, three were waterbirds (Australasian Grebe, Wood Duck, Pacific Black Duck). The Wood Duck often nests in large tree hollows in forest and woodland, but most records in the data set were of ducks on dams rather than at nest hollows. The waterbirds were removed from the data analysis, as they are not primarily woodland species.

3.1 Threatened species and 'species of interest'

Among the 60 species which occur in more than 1% of the woodland surveys are some that are listed as threatened in the ACT, or are of interest because they are believed to be declining in local or regional woodlands. This number of records allows an analysis to be done of longitudinal trends in detection rates. These species are Brown Treecreeper, Dusky Woodswallow, Hooded Robin, Varied Sittella and White-winged Triller. Trends for these species are discussed in section 3.6.1 below.

Several other species of interest were not recorded at a sufficient rate to allow trends to be analysed. Some of these species have limited habitat in the northern ACT, and more information is available about them from other parts of their range. Such species are Superb Parrot, Regent Honeyeater, Painted Honeyeater and Flame Robin.

A third group of species appears in low numbers in the Woodland Survey, despite the presence of apparently suitable habitat. These include the Varied Sittella, Diamond Firetail and Jacky Winter. The Woodland Bird Survey either does not provide sufficient information to analyse population trends in these uncommon species, or the analysis does not show a clear trend (Varied Sittella). More useful information may be gained about such species by targeted surveys.

Table 3. Summary of records of threatened species and 'species of interest'.

Species and status	Records in survey period	Areas recorded	Notes
Regent Honeyeater *Xanthomyza phrygia* Endangered in ACT	1	GOO Nov 98	Rare visitor to ACT
Superb Parrot *Polytelis swainsonii* Vulnerable in ACT	1	GOO Oct 02	Also GOO Dec 04, outside site.
Swift Parrot *Lathamus discolor* Vulnerable in ACT	0	-	14 at MAJ Mar 05, outside site
Brown Treecreeper *Climacteris picumnus* Vulnerable in ACT	81	CAS, GOS, LAM, MAJ, NLN	Most records from CAS, NLN, LAM(all leasehold), rarely at MAJ. GOS is new site (Reserve).
Painted Honeyeater *Grantiella picta* Vulnerable in ACT	3	MUL Nov 02	Rarely recorded in ACT
Hooded Robin *Melandryas cucullata* Vulnerable in ACT	33	CAS, GOO, HAL, LAM, MJF, MUL, NLN	Several sites at GOO, less often recorded elsewhere.
Varied Sittella *Daphoenositta chrysoptera* Vulnerable in ACT	34	CAM, GOO, HAL, MAJ, MJF, MUL, NLN, RED, SYM, TUG	Widespread but uncommon on survey sites. Seen more in Reserves.

Table 3 (continued). Summary of records of threatened species and 'species of interest'.

Species and status	Records in survey period	Areas recorded	Notes
Flame Robin *Petroica phoenicea* 'watching brief' in ACT	5	GOS, HAL, MAJ, NAS, TUG	Also MUL Sep04, outside site.
Crested Shrike-tit *Falcunculus frontatus* 'watching brief' in ACT	11	CAS, CMP, LAM, MUL, NLN	Also GOO Dec02, outside site.
White-winged Triller *Lalage sueurii* Vulnerable in ACT	48	CAM, CAS, GOO, HAL, LAM, MAJ, MJF, MUL, NLN, SYM, TUG	Wide-ranging visitor in drought years.
Dusky Woodswallow *Artamus cyanopterus* 'watching brief' in ACT	78	CAS, GOO, HAL, LAM, MAJ, MJF, MUL, RED, SYM, TUG	Most common at CAS and LAM (discontinued), both leaseholds near Murrumbidgee River.
Diamond Firetail *Stagonopleura guttata* 'watching brief' in ACT Vulnerable in NSW	18	CAS, GOO, HAL, LAM, MJF, NLN	Most (10) records from LAM, a discontinued site, few in reserves. Also occurs at new NAS site.
Jacky Winter *Microeca fascinans*	10	GOO, LAM, NLN, TUG	Few records, LAM discontinued.

3.2 Types of trends in detection rates

The statistical data on longitudinal trends is attached as Table 7. Annotated graphs showing these data with various representations of trends are also attached. The 1998/99 data for many species is markedly different (higher, lower or variable detection rates) from subsequent data. Examples are Australian King Parrot, Brown Treecreeper, Crested Pigeon, Dusky Woodswallow, Eastern Spinebill, Grey Currawong, Magpie Lark, Scarlet Robin, Tree Martin, White-plumed Honeyeater, White-throated Treecreeper, Willie Wagtail and Yellow-rumped Thornbill. The reason for this is not clear, and it may be an artifact of the types of sites surveyed early in the project. This variance in early (and possibly less reliable) survey data may influence the trend in detection rates for some species.

Another more pervasive influence can be seen for species which are more commonly recorded in spring than winter, or vice versa. The initial survey in the period analysed took place in spring, whereas the last survey in the analysis is a winter one. This may result in an apparent change in detection rate, where examination of the graphs suggests otherwise. For example, the linear trend lines on the graph for the Grey Fantail (more often recorded in spring than in winter) suggests a decline in detection rate, but there appears to have been little actual change in the detection rate between winter 1999 and winter 2004.

3.3 Linear longitudinal trends in detection rates

Of the 60 most commonly recorded species (excluding waterbirds), the longitudinal analyses (1998-2004) showed significant declines ($P<0.01$) in probability of detection for 8 species. A further 9 species showed possible declines ($P=0.01$-0.5) over the same period (Table 4). These groups include resident and migratory birds, native and exotic species, hole-nesters, and ground and canopy feeders. A number are common species which are usually considered to have coped well with habitat change in the past.

A decline in the detection rate for a species at woodland survey sites could mean that the population is declining, but could also be due to temporary movements from woodlands to other habitats such as gardens during drought, or into forests regenerating after fire.

An overview of the status of Australia's birds prepared for Birds Australia (SOAB, Olsen *et al.,* 2005) reviewed data from two nationwide Atlas survey periods and from various regional studies. The SOAB report noted that 13% of Australian woodland bird species were declining, and that this figure rose to 24% for ground feeding woodland bird species. The ACT report in the SOAB was prepared in August 2005 from a preliminary inspection of the Woodland Survey data. It was based on data for 61 woodland birds from 142 monitoring points at 13 locations, collected between spring 1998 and winter 2004, which provided the following trends:

- 18 species (29%) showed clear declines in detection rates, including Eastern Rosella, Red-rumped Parrot, Willie Wagtail, Superb Fairy-wren, Grey Currawong, and the introduced Common Starling and Common Myna – mainly ground feeders. Others are summer migrants such as the Noisy Friarbird, Dusky Woodswallow and Black-faced Cuckoo-shrike
- 4 species (7%) showed increases in detection rate; these include Speckled Warbler, Common Bronzewing and Golden Whistler
- 10 species (16%) had stable detection rates; these include Weebill, Rufous Whistler, Laughing Kookaburra, Crimson Rosella, Australian Magpie, Western and White-throated Gerygones and Scarlet Robin
- the remaining 29 species (48%) showed irregular patterns of detection or indistinct trends (mostly declines); this group includes Red Wattlebird, Grey Fantail, Pied Currawong, as well as the two ACT threatened species Hooded Robin and Brown Treecreeper.

(from Olsen *et al. 2005)*

Table 4: Species showing decline in detection rate, September 1998 to June 2004.
(most recent analysis)

Species	**Decline in detection rate**
P < 0.01	
Eastern Rosella	10%
Tree Martin	18%
Willie Wagtail	17%
Black-faced Cuckoo-shrike	20%
White-plumed Honeyeater	14%
Noisy Friarbird	23%
Grey Currawong	20%
Common Starling	14%
P = 0.01 – 0.05	
Red-rumped Parrot	10%
Grey Fantail	9%
Superb Fairy-Wren	11%
Dusky Woodswallow	14%
Mistletoebird	19%
Spotted Pardalote	7%
Olive-backed Oriole	26%
Striated Pardalote	5%
Common Mynah	15%

Only three species showed a significant increase in detection rate (P<0.01), and none were in the possible increase group (P=0.01-0.5) (Table 4).

Table 5: Species showing increase in detection rate, September 1998 to June 2004

Species	Increase in detection rate
P < 0.01	
Golden Whistler	26%
***Speckled Warbler**	**19%**
Yellow-faced Honeyeater	7%

* listed in NSW as vulnerable

The probability of detection for some species changed little for most of the period. These include Australian Magpie, Crimson Rosella, Noisy Miner, Rufous Whistler, Scarlet Robin, Striated Pardalote, Sulphur-crested Cockatoo and Weebill.

3.4 Other trends in detection rates

A regular seasonal cycle in probability of detection is seen in many species, both resident and migratory. The detection rates for many species varied during the period, without showing a significant pattern or unidirectional trend. These data are best displayed in the attached graphs showing the variation in detection rates over the period.

3.4.1 Drought

Examination of the attached graphs for a number of species shows an apparent decline in the probability of detection in recent years (2001-2004). This may be due to the effects of the prolonged drought on bird populations, perhaps compounded for some species by the loss of forest habitat in the January 2003 fires. Recently declining detection rates were found in the Buff-rumped Thornbill, Common Starling, Dusky Woodswallow, Grey Currawong, Hooded Robin, Nankeen Kestrel, Tree Martin and White-throated Treecreeper, all primarily insect eaters. Two species which showed an apparent increase in detection rate during the drought were the Galah and Crested Pigeon. These species eat seeds of both native and exotic plants. An increase in the detection rate could be due to birds moving onto the tablelands from the inland during drought.

Some of the survey sites had more or less permanent water (dams) within 50 metres. Most of these sites are on leasehold land. Bird numbers at these sites may have been elevated during the drought, and the presence of water in dry times may be of overriding importance, obscuring the effects of other habitat parameters.

3.4.2 Bushfires

A number of species showed a marked decrease in detection rates in the last two surveys in this data set (autumn and winter 2004). These were almost exclusively species which prefer to nest in the forested ranges and overwinter in the lowland woodlands: Brown Thornbill, Golden Whistler, Grey Shrike-thrush, Silvereye, Sulphur-crested Cockatoo, White-eared Honeyeater, White-naped Honeyeater and Yellow-faced Honeyeater (and possibly Scarlet Robin). It is likely that the decrease in detection rates in the woodlands in autumn and winter 2004 is due to the extensive loss of breeding habitat in the January 2003 fires. The decline was not seen in the season immediately following the fires, suggesting that the birds had already moved to the lowlands when the forests burnt. The COG Annual Bird Report for the year ending June 2004 also reported that a 'surprising number of honeyeater species' (including those above) and the Golden Whistler were not recorded as breeding in the Canberra district in the spring following the bushfires (CBN 2005).

The detection rate for Noisy Miners also fell sharply at this time. This is a species of open woodland, with little eucalypt regeneration or shrub cover. Much less of this habitat was affected by the bushfires, which makes it more difficult to explain the fall in detection rate. It would be interesting to analyse other COG records for this species in 2004 to see if Miners had spread into previously dense woodland or forest areas which had been opened up by the fires. This could account for lower numbers being recorded in the woodland surveys, or it could be the cumulative effect of several drought seasons.

Some species also showed a decreased detection rate in the spring and summer period following the fires. This could be due to loss of birds or habitat in the fires, and/or the cumulative effects of the prolonged drought. These species include the Pallid Cuckoo, Leaden Flycatcher, Black-faced Cuckoo-shrike and Grey Shrike-thrush.

3.5 Effects of land tenure and habitat variables

3.5.1 Background

The designations of 'leasehold' and 'reserve' are intended to help in the examination of the effects of past and current grazing by stock, and other management differences between the land tenures. However, the intensity of grazing on leased land varies considerably, and length of time since last grazing in reserves also varies. For example, Mulligans Flat was leasehold land just before the start of bird surveys there, but has now been ungrazed by domestic stock for about 8 years, while numbers of kangaroos have increased. The Majura Training Area (MJF, Field Firing Range) has been ungrazed for a similar period and is managed somewhat like a reserve, but appears in the analyses as leasehold land. Goorooyarroo Reserve (GOS) was grazed until early 2004, when it changed from leasehold to reserved land, and Gooroo (GOO) was formerly leasehold but is now also part of Goorooyarroo Reserve. Limited grazing is used in part of Goorooyarroo to control exotic grasses.

There are probably other general differences between leasehold and reserve land in the ACT. Much of the reserved woodland is on the lower slopes of hills and ridges, while leasehold land has taken up the valley floors. The effects of land management will therefore overlie existing differences in soil depth, fertility and moisture, which will also affect the plant and animal populations. Leasehold land also contains permanent water sources for stock, which may favour some bird species.

Some of Ross Cunningham's analyses of habitat variables against tenure help to explore this complex situation (see species treatments below). The graphs of these analyses are interspersed with the species graphs at the end of this report. Collection of some other habitat variables for the survey sites would also be useful. This should include information on tree diameter, site topography, distance to nearest water source and grazing history. Patch size and connectivity have not yet been considered, and these attributes are probably best assessed from recent aerial photography and Environment ACT vegetation community mapping.

One further consideration should be taken into account when examining habitat measures and detection rate trends during the period of this survey. Each survey site has been allocated one set of averaged habitat measures, derived from two or more habitat surveys. This will not be an accurate reflection of the habitat condition at a number of sites, where the structure will have changed due to fire, drought, grazing, tenure change etc. It was decided to use one averaged habitat 'snapshot' to enable analyses to be done for the current period, but habitat surveys should continue to be undertaken to measure changes, and all these surveys would be available for future analyses.

3.5.2 Some characteristics of leasehold and reserve land

Habitat surveys for 48 leased and 84 reserve sites were analysed. This showed that, compared to reserves, leasehold sites tended to have less eucalypt regeneration and fewer large shrubs, and were more likely to have an exotic-dominated ground layer and poor tree health. These differences could be due to the effects of grazing and pasture improvement.

Leasehold sites were also somewhat more likely to have a high number of tree hollows and mistletoes. This did not appear to be due to a higher density of mature trees, but could be related to poorer tree health, to less frequent fires on leased land, or to differences in the tree species composition. It is known, for example, that Yellow Box has been selectively removed from some leasehold land, and that the rate of hollow formation varies from species to species. Mistletoes can become more abundant with habitat fragmentation, as they thrive on the edges of clearings (Watson 2004).

Further (non-statistical) inspection of the mistletoe data showed that higher mistletoe numbers were correlated with sites where a species of box was the dominant tree (Yellow Box, Red Box or Apple Box). All the sites with more than 20 mistletoes were dominated by a species of box, compared to only 50% of sites with no mistletoe. This may be because the mistletoe species parasitic on Red and Yellow Box in the ACT (*Amyema miquellii*) is more common than *Muellerina eucalyptoides* which occurs on Blakely's Red Gum (Burbidge and Gray 1970). It was not determined whether box species were more common on leased land. Apple Box is often found on deeper better-watered soils, which are more likely to be under leasehold.

3.6 Case studies

In this section a selection of species are discussed in taxonomic order (with the threatened group discussed separately). Table 5 contains brief comments on all species analysed, illustrated by the attached graphs.

3.6.1 Threatened species and species of interest

Brown Treecreeper

Detection rates for this species have been low but fairly stable since 1999, with peaks in summer and winter. The probability of detection was higher on leasehold land than in reserves, and also where trees were healthy rather than affected by dieback (as measured by canopy loss). Interestingly, healthy trees were more likely to be found in reserves, so the leasehold sites where this species occurs may be a subset that varies from the usual habitat parameters for leasehold land. However, there is also a positive correlation between tree hollows and treecreepers, and tree hollows and leasehold sites. This may be a reflection of tree age/size on sites containing Brown Treecreepers.

Hooded Robin

Small populations of Hooded Robins occur consistently at or around particular monitoring points in some survey areas, but are not widespread in those areas. Detections of this more sedentary species also appeared to increase slightly during the drought and decline sharply after the bushfires, but there is no easily explained trend. The tenure graph shows differing non-linear trends for reserve and leasehold land, but detections declined under both tenures in 2003-2004.

Many of the survey records come from the northern woodlands which extend from Hall to Newline Quarry. Given the relatively low number of records and apparent recent decline, this species warrants more targeted surveys in this area.

White-winged Triller

This species is usually only recorded in the summer surveys, and the detection rate varies from year to year. There are often more records in the ACT area when the inland is affected by drought.

Dusky Woodswallow
The analysis suggests a slight decline in the detection rate for this mobile species, but the graph could also show an irregular pattern, with an increase during the drought followed by a decline after the January 2003 bushfires. The species was more frequently recorded near the Murrumbidgee River corridor, an area where many trees were lost in the fires.

Varied Sittella
The detection rate for this species is mostly low, usually with a peak in spring. Records were unusually low in the 5 surveys following the January 2003 bushfires, but there were more records in the last survey (winter 2004). It was recorded more frequently in reserves than on leased land. Many woodlands in ACT reserves adjoin sclerophyll forest, a habitat also used by this species.

Diamond Firetail
10 of the 18 records in the survey period were at Lambrigg (LAM, a discontinued site), and few were found in reserves. The species occurs at the new NAS site, but the low number of records and restricted distribution in the surveys overall suggests that this species warrants more targeted study. It is noted that since early 2003, Diamond Firetails have been reported at a number of other locations around Canberra, including some burned and cleared pine forest areas near urban fringes, as well as in Goorooyarroo and Callum Brae Nature Reserves.

3.6.2 Other species
Crimson Rosella, Eastern Rosella, Red-rumped Parrot, Sulphur-crested Cockatoo and Galah
Detection rates for Crimson Rosella were high and relatively steady throughout the survey period, with a possible increase in spring 2003 (following the bushfires) and a decline in the following winter. This may be due to more birds breeding in the woodlands after the loss of forest, and lower numbers overwintering in the lowland woodlands due to the overall loss of forest breeding/feeding habitat in the region. If a greater number of Crimson Rosellas are seeking nest hollows in woodland, they may come into direct competitions with smaller species which nest mainly in woodland, such as Eastern Rosellas and Red-rumped Parrots.

Eastern Rosellas showed a steady decline in detection rate, while Red-rumped Parrots declined until 2003 but showed a slight increase in 2004. Both are species of more open woodlands, and may compete with native and feral species for nest hollows (Pell & Tidemann 1997). However, detection rates for Nankeen Kestrels, Common Starlings and Common Mynahs also declined during the survey period, suggesting that they may be under the same pressures as the small parrots. This could be due to an overall shortage of nest hollows in the woodlands or increased competition for them, or depletion of their foods in the ground layer due to drought and/or overgrazing.

The detection rate for Galahs declined from 1998 to 2001, and increased from 2001 to 2004. The recent increase could be associated with Galahs moving to escape drought further inland, which could increase competition for nest hollows in ACT woodlands, to the detriment of smaller hollow-nesting species.

Sulphur-crested Cockatoos were detected at a fairly steady rate throughout the survey period, with a possible decline in winter 2004.

Superb Fairy-wren
The detection rate has declined steadily for this species, with a steeper drop in 2004. Detailed long-term population studies of Superb Fairy-Wrens in the Australian National Botanic Gardens by ANU researchers show a similar decline (Michael Double, pers. comm.). The Botanic Gardens is a partially irrigated site where the effects of the drought should not have been as great.

Speckled Warbler
This ground-feeding and low-nesting species is listed as vulnerable in NSW. There has been a statistically significant increase in the detection rate for this species in the ACT woodland survey area. The previous report on this survey (Rowell 2004) showed that this species was widespread but uncommon, and associated with fairly complex habitat structure. There were 120 sightings of Speckled Warblers, in 11 of the 13 areas surveyed. The data which has been collected during this survey on distribution and habitat of the species could be analysed in more detail, with reference to recent research on the species in the ACT by Dr Janet Gardner.

Buff-rumped and Yellow-rumped Thornbills
There was a marked seasonal variation in the detection rate of Buff-rumped Thornbills, with a regular peak in spring. The probability of detection was higher in reserves than on leased land, but the correlation was not as marked in the later stages of the drought. Before 2003, there was also a strong correlation with a tussocky complex ground layer, which non-statistical analysis showed was most often dominated by native plant species (in turn shown by statistical analysis to be associated with reserve sites). During the drought, the detection rate in this vegetation type declined. The structure of the ground layer under the different tenures may have converged during the recent drought due to overgrazing by both stock and kangaroos, but such a change in habitat structure is not captured by the single habitat assessment. Birds could also tend to stay in leasehold areas containing dams during the drought. This supposition is supported by a significant correlation between leasehold land and a ground layer described as ‘short-medium height, medium density, fairly even’. The detection rate of Buff-rumped Thornbills on this ground cover type did not decline.

Yellow-rumped Thornbills showed quite a different pattern. There was no seasonal regularity in the detection rate, which increased in 2003 and declined dramatically in 2004. Examination of the trends by land tenure showed that this change took place on leased land, whereas detections in reserves showed a continuous decline. It is possible that the species moved to grazed areas with dams during the drought, but were unable to breed there due to the lack of eucalypt regeneration and shrub cover. The causes of the variation need further investigation by tenure, site and seasonal conditions.

Foliage gleaners/canopy feeders v ground feeders
Several small canopy feeding species show relatively stable detection rates. These include White-throated Gerygone, Western Gerygone, Weebill, Striated Thornbill, Spotted Pardalote and Striated Pardalote. This is in contrast to several other small species that feed mainly on the ground or in lower vegetation layers (Willie Wagtail, Buff-rumped Thornbill, Superb Fairy-wren, Red-browed Finch).

Noisy Friarbird
This species was consistently more likely to be detected in reserves than on leased land, but the detection rate declined for both tenures during the survey period.

Noisy Miner
Noisy Miners were significantly more likely to occur on sites with little or no eucalypt regeneration and few or no tall shrubs. This vegetation structure is strongly correlated with grazed sites.

Rufous Whistler
The longitudinal detection rate for this species appears fairly stable. They were more likely to be detected on leased land early in the survey period, but the detection rate declined more steeply on leased land during the drought (2001-2004).

White-winged Chough
The detection rate for this species increased during the drought. Analysis of numbers of birds recorded per site could show whether this was due to fragmentation of groups in the face of reduced resources. During the drought, the detection rate was stable on sites where tree health was moderate, but increased where tree health was good (associated with reserves). Choughs were mostly absent from areas where tree health was poor (probably grazed woodlands).

Common Mynah and Common Starling
The detection rate for both species declined between 2001 and 2004. Starlings were more likely to be detected on leased land, but the detection rate for both land tenures declined after 2001, and there was an extra drop in Starling records in winter 2004. The results for both species could be due to the effect of the drought on survival and breeding. For both species there was a more marked reduction on sites where there were no mistletoes. It is not clear what has caused this. 38 survey sites have no mistletoes, including all 9 sites at Red Hill, and 18 of the 24 Mulligans Flat sites, 9 of the 18 being open forest rather than woodland.

4. CONCLUSIONS

4.1 Prediction Inference

A feature of data for most species is large inherent variability in the observed detection data, and evidence of large inter-year as well as large intra-year variability in detection rates. For these reasons, inferences relating to long-term trends based on simple linear effects may not be useful. Further, given the fact that prediction is inherently more difficult than estimation of trends (see Appendix 1) it is unlikely that precise (direct) prediction of long term outcomes will be possible. However, close inspections of long term patterns summarised in the graphs provide useful information for indirectly assessing long-term trends. Clearly, the longer the period of survey the more confident indirect prediction will be.

4.2 Implications of trends

Results for individual species may vary, but it is notable that many more species showed a decline in detection rates than an increase. As discussed above, a broad range of species had declining detection rates, including resident and migratory species, native and exotic species, hole-nesters, and ground and canopy feeders. A number are common species which are usually considered to have adapted well to modified and simplified habitats. Even the fact that the same decline is seen in records of two feral species is of concern, as these species are opportunistic and adaptable.

The trends for many species show recent changes which are probably associated with the recent drought and severe bushfires. The increased rainfall in 2005 will affect the breeding and survival of birds, and future analyses may show differences in how quickly different species recover. Recovery from the effects of the January 2003 bushfire can also be charted. The Woodland Bird Survey is providing data that will be useful in developing management guidelines for woodlands in reserves and on leasehold land in the ACT. The data can also be very valuable in adding detail to broader regional studies such as those being carried out by NSW Department of Environment and Conservation on the woodland birds of the sheep-wheat belt.

5. RECOMMENDATIONS FOR FUTURE INVESTIGATIONS AND ANALYSES

- Future analyses should be carried out using data from a period that begins and ends with the same season. This will reduce error in the linear trend for species that have a strong seasonal variation in occurrence or detection. If the whole data set is to be analysed, this could start with spring 1998 and finish with spring 2005. The statistician should be consulted about the reliability of the data in the first year of surveys, which are often at odds with the following series of surveys. It would also be desirable for the January 2003 bushfires to be marked on the horizontal axis of all the graphs showing trends in detection rates, as the fires appear to have had a significant effect on the trend for many species.

- The broad designations of 'leasehold' and 'reserve' are not the best descriptors of the condition of the woodlands for the purposes of statistical analysis. In future analyses, it would be better to use other parameters such as density of woodland, amount of eucalypt regrowth or shrub cover and structure/quality of ground layer which result (in part) from the grazing history of a site (as was done for some species in the current analyses). A measure of time since grazing and the intensity of recent grazing could also be included.

- Some habitat variables can change significantly after drought or bushfire. Immediate post-fire habitat reassessments at Red Hill and Lambrigg generally gave lower scores, due to loss of mature canopy, eucalypt regeneration, shrub layers, hollows and mistletoes, but single values have been used for habitat variables in the analyses, as though they were fixed for the survey period. It will therefore be necessary to carry out the habitat assessments again soon for each survey site, to allow these data to be updated for future analyses. It would be desirable for the surveys to be carried out by one person (using the quantitative data sheet) for consistency, preferably in spring 2006 or autumn 2007.

- Species of concern which appear in low numbers in the Woodland Survey despite the presence of apparently suitable habitat warrant more targeted surveys. These include:

    - Brown Treecreeper
    - Hooded Robin
    - Varied Sittella
    - Southern Whiteface
    - Diamond Firetail
    - Jacky Winter
    - Double-barred Finch.

The current survey does not provide sufficient information to detect population trends in these species. Sites known to contain these species could be selected from the COG database and added to the survey. If sites were added to the existing survey, it would be possible to minimise the volunteer input needed by reducing the number of surveys to one or two per year for the new sites, but doing them in season(s) appropriate for the detection of the target species. The data could then presumably be analysed with the target species records from the existing sites for the same season(s).

- There are sufficient sightings of Speckled Warblers, (120, in 11 of the 13 areas surveyed) to allow the habitat and distribution data to be analysed in more detail, with reference to recent research on the species in the ACT. This is not a priority species for further work within the woodland project.

- Other data in the survey and habitat database could be analysed separately, and may yield valuable insights into the condition of local woodlands. An example is data on tree hollows and hollow-nesting species, which come under particular pressure in woodlands managed for agriculture, and in areas subject to fire.

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Table 6. Summary of trends for species which occurred in more than 1% of surveys.

('Unclear' trend = irregular detection rates, recent decline following stability, other non-linear trends which may be clarified by analysis of further surveys)

Species	Trends in detection rate (**Bold** = ACT threatened species)	Indicative Trend
Common Bronzewing	Detection rate steady, then increased during drought and after bushfires.	Increase
Crested Pigeon	Detection rate steady, then increased in 2004 (late drought, post-bushfires).	Stable
Nankeen Kestrel	Steady decline, possible increase late drought/after bushfires.	Decrease
Sulphur-crested Cockatoo	Detection rate high and steady, decrease autumn and winter 2004.	Unclear
Galah	Decline 1998-2001, increase during drought (2002-2004). Possibly birds moving from inland.	Unclear
Australian King-Parrot	Altitudinal migrant, forest-nesting. Slight steady increase, also noted in Garden Bird Survey.	Increase
Crimson Rosella	Detection rate fairly steady, possible decrease winter 2004.	Stable
Eastern Rosella	High detection rate, steady decline throughout survey period.	Decrease
Red-rumped Parrot	Decline 1998-2002, slight increase 2003-2004.	Decrease
Laughing Kookaburra	Detection rate varies slightly.	Unclear
Pallid Cuckoo	Steady increase until 2003, reduced detections in spring 2004 (Possibly late drought or post-fire effect).	Unclear
Welcome Swallow	Detection rate variable, possible slight decline	Unclear
Tree Martin	Detection rate variable, possible slight decline	Unclear
Grey Fantail	Analysis suggests decline, but detection rate possibly steady. Increased during drought where ground cover sparse.	Unclear
Willie Wagtail	Slight decline, with possible increase in winter 2004. Marked decline where eucalypt regeneration dense, slight increase where absent. See text discussion for Superb Fairy-wren.	Unclear
Leaden Flycatcher	Low numbers in spring/summer 2003, possible effect of Jan 03 bushfires.	Unclear
Scarlet Robin	Steady, but low numbers winter 2004. Possibly due to reduced breeding in forests post-bushfire.	Stable
Hooded Robin	**Detection rate irregular, with sharp decline in 2003-2004.**	**Unclear**
Golden Whistler	Steady increase in overwintering birds until 2004, then steep decline. Possibly due to lack of forest breeding areas post-fire.	Unclear
Rufous Whistler	High and relatively steady spring and summer detection rate. May have declined on leased land during drought.	Stable
Grey Shrike-thrush	Variable, with a steep decline 2003-04 (possible post-fire effect).	Unclear
Magpie-lark	Relatively steady detection rate.	Stable
Black-faced Cuckoo-shrike	Variable detection rate, with decrease in spring 2003 (possible post-fire effect).	Unclear
White-winged Triller	**Variable detection rate, high numbers summer 2003/04 – possibly due to inland drought.**	**Unclear**
White-throated Gerygone	Irregular, with lower numbers in summer 2000-01 and 2003-04. Very similar to Western Gerygone.	Unclear
Western Gerygone	As for White-throated Gerygone.	Unclear
Weebill	High steady detection rate, lowest in autumn and highest in winter.	Stable
Striated Thornbill	Detection rate fairly steady, with seasonal variation.	Stable
Brown Thornbill	Variable detection rate, peaks in winter. Steep decline 2004 – possibly due to loss of forest breeding habitat in bushfires.	Unclear

Species	Trends in detection rate	Indicative Trend
Buff-rumped Thornbill	Possible decline during drought. Associated with reserves, and native ground layer before drought.	Unclear
Yellow-rumped Thornbill	Irregular detection rate, without clear seasonal effects. See text for discussion.	Unclear
Speckled Warbler	Irregular but apparently increasing detection rate. Widespread in survey area.	Unclear
Superb Fairy-wren	Steady decline, steeper in 2004.	Decrease
Dusky Woodswallow	Detection rates stable since 1999, higher on leasehold land than in reserves (see text).	Unclear
Varied Sittella	**Detections mostly low but variable, possible decline after bushfires. More often in reserves than leasehold.**	**Unclear**
Brown Treecreeper	**Detection rate low but fairly stable since 1999, more frequent on leasehold land than in reserves.**	**Unclear**
White-throated Treecreeper	Non-linear trend, with apparent decline since 2001.	Unclear
Mistletoebird	Possible slight decline in overall detection rate. Fewer records and greater decline in leasehold areas.	Decrease
Spotted Pardalote	Non-linear pattern. Winter/spring peaks, summer troughs. Low winter numbers in 2003, high in 2004.	Unclear
Striated Pardalote	Analysis suggests slight decline, may be stable. Spring and autumn peaks.	Unclear
Silvereye	Non-linear trend, with autumn peaks. Near failure of autumn migration in 2004.	Unclear
White-naped Honeyeater	Irregular detection. Absent summer, peaks autumn/spring (migration). Few autumn/04, possibly reduced breeding post-fire	Unclear
Brown-headed Honeyeater	Detection rate low, trend non-linear.	Unclear
Eastern Spinebill	Irregular, possibly relatively stable. Numbers high autumn 2004, low winter 2004.	Unclear
Yellow-faced Honeyeater	Peaks in autumn, spring (migration). High spring/03, low in following autumn. Possibly less breeding in ranges after fires.	Unclear
White-eared Honeyeater	Non-linear trend. Peaks of overwintering birds in lowlands, very high in winter following bushfires, but low in the next winter (2004). Possibly reduced breeding in ranges following fires.	Unclear
White-plumed Honeyeater	Possible slight decline in detection rate.	Unclear
Noisy Miner	Detection rate high and stable, until steep decline in autumn/winter 2004.	Stable
Red Wattlebird	Non-linear trend. Possible slight increase 2001-2004.	Unclear
Noisy Friarbird	Declining detection rate. More records from reserves, but declining under both tenures.	Decrease
Red-browed Finch	Non-linear trend. Apparent decline during drought.	Unclear
Double-barred Finch	Low detection rate, mainly on leased land. Increase in records from reserves in 2003-04.	Unclear
Olive-backed Oriole	Summer visitor, irregular numbers, apparent decline during drought.	Decrease
White-winged Chough	Increasing detection rate 2001-2004. Positive correlation with good tree health (see text).	Increase
Pied Currawong	Non-linear trend. Apparent decline in detection rate in winter 2004.	Unclear
Grey Currawong	Declining detection rate. Unclear recent trend following drought and fire.	Decrease
Grey Butcherbird	Fairly steady detection rate.	Stable
Australian Magpie	Detection rate stable.	Stable
Australian Raven	Steadily increasing detection rate, with possible decline in winter 2004.	Increase
Common Myna	Steady decline in detection rate 2000-2004. Possible drought effect	Decrease
Common Starling	More common on leased land. Detection rate down 2001-2004 in both tenures, steeper in 2004. Possible drought effect.	Decrease

Table 7. Overall % change (based on the adjusted linear fit) in the odds of detection for species which occur in more than 1% of surveys, associated observed significance level (p-value) and approximate 95 % Confidence Intervals (bold figures are P < 0.05).

			95% Confidence Interval	
RAOUName	**%Change**	**p-value**	**Lower Bound**	**Upper Bound**
Common Bronzewing	19.36	0.09	-3.19	47.16
Crested Pigeon	-0.86	0.93	-18.14	20.07
Australasian Grebe	6.16	0.69	-21.37	43.33
Australian Wood Duck	5.67	0.46	-9.12	22.87
Pacific Black Duck	-6.56	0.58	-26.93	19.48
Nankeen Kestrel	-8.52	0.52	-30.61	20.60
Sulphur-crested Cockatoo	2.21	0.65	-7.32	12.73
Galah	-3.25	0.39	-10.46	4.55
Australian King-Parrot	12.41	0.24	-7.76	36.99
Crimson Rosella	-0.93	0.77	-7.14	5.70
Eastern Rosella	-9.01	**7.23E-03**	-15.18	-2.39
Red-rumped Parrot	-15.52	**0.03**	-27.81	-1.14
Laughing Kookaburra	-5.89	0.46	-20.16	10.92
Pallid Cuckoo	10.02	0.53	-19.04	49.51
Welcome Swallow	-6.71	0.66	-31.64	27.32
Tree Martin	-24.42	**1.56E-03**	-36.67	-9.81
Grey Fantail	-7.98	**0.02**	-14.26	-1.23
Willie Wagtail	-22.93	**1.16E-03**	-34.34	-9.54
Leaden Flycatcher	-12.36	0.21	-29.14	8.39
Scarlet Robin	-0.93	0.89	-13.02	12.83
Hooded Robin	-18.57	0.15	-38.90	8.52
Golden Whistler	28.62	**1.98E-03**	9.33	51.31
Rufous Whistler	2.58	0.61	-7.06	13.23
Grey Shrike-thrush	2.02	0.79	-12.46	18.90
Magpie-lark	-9.80	0.13	-21.42	3.54
Black-faced Cuckoo-shrike	-22.49	**1.80E-06**	-30.31	-13.79
White-winged Triller	-10.48	0.48	-34.54	22.41
White-throated Gerygone	-8.32	0.17	-19.12	3.93
Western Gerygone	-5.02	0.56	-20.40	13.33
Weebill	1.14	0.74	-5.45	8.19
Striated Thornbill	6.60	0.19	-3.39	17.63
Brown Thornbill	-4.66	0.54	-18.50	11.54
Buff-rumped Thornbill	-6.85	0.07	-13.88	0.76
Yellow-rumped Thornbill	-4.40	0.41	-14.19	6.52
Speckled Warbler	23.24	**3.79E-03**	6.69	42.37
Superb Fairy-wren	-8.52	**0.03**	-15.65	-0.79

			95% Confidence Interval	
RAOUName	**%Change**	**p-value**	**Lower Bound**	**Upper Bound**
Dusky Woodswallow	-21.16	**4.69E-02**	-37.94	0.14
Varied Sittella	-14.21	0.27	-34.97	13.18
Brown Treecreeper	-10.14	0.41	-30.62	16.39
White-throated Treecreeper	0.39	0.94	-9.15	10.94
Mistletoebird	-12.44	**0.04**	-23.22	-0.14
Spotted Pardalote	-8.67	0.05	-16.84	0.29
Silvereye	8.91	0.27	-6.58	26.98
White-naped Honeyeater	-22.13	0.11	-43.19	6.73
Brown-headed Honeyeater	8.44	0.38	-9.67	30.19
Eastern Spinebill	5.16	0.66	-16.49	32.43
Yellow-faced Honeyeater	16.39	**7.48E-03**	3.91	30.36
White-eared Honeyeater	3.85	0.65	-12.06	22.65
White-plumed Honeyeater	-19.48	**3.57E-04**	-28.67	-9.11
Noisy Miner	2.24	0.62	-6.45	11.74
Red Wattlebird	-6.31	0.18	-15.07	3.35
Noisy Friarbird	-21.57	**1.52E-05**	-29.89	-12.27
Red-browed Finch	-7.91	0.55	-29.95	21.06
Olive-backed Oriole	-21.65	**0.03**	-37.36	-1.98
White-winged Chough	12.65	0.13	-3.93	32.09
Pied Currawong	7.11	0.17	-3.13	18.42
Grey Currawong	-23.54	**9.63E-03**	-37.84	-5.94
Grey Butcherbird	7.98	0.45	-12.01	32.51
Australian Magpie	1.58	0.64	-5.02	8.64
Australian Raven	7.18	0.24	-4.74	20.60
Striated Pardalote	-6.81	**0.04**	-12.90	-0.29
Common Myna	-13.65	**0.03**	-24.49	-1.25
Common Starling	-26.75	**3.30E-09**	-34.04	-18.66

APPENDIX 1: Discussion of prediction and estimation of trends

Ross Cunningham

The complicated mean and dependence structure in the models fitted to the bird detection data complicate discussion of the nature and form of prediction inference. Since the issues are all already present in much simpler models, it makes sense to simplify the context. Thus for simplicity we consider the very simple problem in which observed data $Y_1,...,Y_n$ are distributed as independent Gaussian random variables with unknown mean μ and known variance σ^2. In this context, the nature and form of prediction inference is considered by comparing it to classical inference for μ. Essentially the mathematical underpinning is provided to show that ***prediction is inherently more difficult than estimation and valid prediction inferences have to reflect this fact.*** It is worth emphasising that changing the model and introducing extra complexity change the form of inference but not the conceptual issues underlying it.

Most statistical inference is concerned with estimating the mean μ. The usual approach is to use the sample mean

$$\overline{Y} = n^{-1}\sum_{i=1}^{n} Y_i$$

as the estimator of μ. The sample mean can be shown to satisfy

$E(\overline{Y} - \mu) = 0$ and $E(\overline{Y} - \mu)^2 = \sigma^2 / n$.

In addition , the sample mean has a Gaussian distribution so that

$U_\mu = n^{1/2}(\overline{Y} - \mu)/\sigma$ has a standard Gaussian distribution. By expressing probability statements about U_μ in terms of μ, we obtain the well known 95% confidence interval for μ of the form

$[\overline{Y} - 1.96\sigma / n^{1/2}, \overline{Y} + 1.96\sigma / n^{1/2}]$.

Now suppose we want to predict the value of an observation $Y_{k,}$ $k > n$, which has the same distribution as $Y_1,...,Y_n$ and which is independent of $Y_1,...,Y_n$. Essentially, we need to replace μ by Y_k in the discussion leading to the above confidence interval.

However, μ is fixed and Y_k is random so now we find

$E(\overline{Y} - \mu) = 0$ and $E(\overline{Y} - \mu)^2 = \sigma^2 / n + \sigma^2 = \sigma^2(1/n + 1)$. The different form of the second expression is the key to understanding the difference between confidence and prediction inference. In the prediction case, $U_\mu = (\overline{Y} - Y_k)/\sigma(1/n + 1)^{1/2}$ has a standard Gaussian distribution so expressing probability statements about U_μ in terms of Y_k, we obtain the well known 95% prediction interval for Y_k of the form

$[\overline{Y} - 1.96\sigma/(1/n + 1)^{1/2}, \overline{Y} + 1.96\sigma/(1/n + 1)^{1/2}$.

Since $\sigma > 0$, we see that the prediction interval is wider than the confidence interval for μ. In addition, as n increases we see that the 95% confidence interval tend to the point $\overline{Y}$, namely μ, while the prediction interval tend to $[\mu - 1.96\sigma, \mu + 1.96\sigma]$. In other words, with a large sample as is the case here, we can estimate μ accurately but we can never predict Y_k exactly. This is very important and explains why prediction intervals are observably wider than confidence intervals and much wider when n is large and the model does not account for much of the variation in $Y_1, ..., Y_n$.

Form A: **COG Woodland Bird Survey: Sub-site Habitat Complexity Assessment**

Site	Sub-site	Date	Observer

	0	1	2	Score
1. Tree canopy >6m tall, % cover	<1% >40%	1-10%	11-40%	
2. Eucalypt regeneration <6m tall, % cover	<1% >50%	1-10% 26-50%	11-25%	
3. Number of tree species (>6m) (indicate species if known, and proportion)	1	2-3	4 or more	
4. Gross tree health: % of eucalypt canopy (all age classes) with significant leaf damage or loss	>50%	10-50%	<10%	
5. Tall shrubs/small non-eucalypt trees (2-6m), % cover (indicate species if known)	<1% >50%	1-10% 26-50%	11-25%	
6.Shrubs 0.5-2m, % cover (indicate species if known)	<1% >50%	1-10% 26-50%	11-25%	
7. Fill in **only** if all shrub cover (0.5-6m) >20%: % of shrub cover that is native	0-25%	>25%		
8. Ground layer (if you wish, make notes on main grass species, level of grazing, bare ground, major weeds etc on back of sheet)	tall and dense **or** short and very sparse	short/medium height and density, fairly even	Patchy, tussocky, **or** with many sub-shrubs, varying height/density	
9. % of ground layer that is native	<10%	10-50%	>50%	
10. Log/branch/stump, % cover	<1%	1-10%	>10%	
11. Number of tree hollows	0	1-5	>5	
12. Number of mistletoes	0 >40	1-5 21-40	6-20	
TOTAL				

NOTES: Indicate other relevant features of site, e.g. proximity to water source, cleared land, exotic vegetation, houses, gardens, rubbish tip; isolated woodland patch, erosion, other damage/disturbance etc.