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Fluctuations in numbers of Grey Fantails in the Hunter Region of New South Wales

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Summary. Surveys in woodland at Green Wattle Creek (GWC) near Paterson, in the Hunter Region of New South Wales, over 165 consecutive months between 1996 and 2009 have provided a comprehensive understanding of annual and seasonal variation in the abundance of Grey Fantails *Rhipidura albiscapa*. A period of increasing abundance between 1996 and 2002 was followed by a decline between 2003 and 2009. These trends are attributed to a combination of variation in rainfall and the impact of removal of cattle. The monthly variation in abundance of Grey Fantails involved: (a) stable numbers during the breeding season between October and December, when Grey Fantails were well dispersed; (b) low numbers in January–February, probably as a result of poor survey conditions; (c) low numbers in winter (June–July), typically ~70% of breeding-season numbers; and (d) a pronounced peak in abundance in September and a less pronounced, but more protracted, peak between March and May, which are attributed to migration. In June 2006, numbers of Grey Fantails were exceptionally low, apparently as a result of the prolonged drought conditions prevalent at that time, involving a particularly dry first six months of the year. However, in similar surveys conducted quarterly at a farm adjacent to GWC, where most of the remnant vegetation occurred at the edges of creeks, the decline was minor. It is suggested that under drought conditions resident Fantails leave drier woodland areas in the Hunter Region during winter. However, the trends can also be explained by the adverse impact of drought in south-eastern Australia on Fantails breeding in that area and wintering in the Hunter Region. Counting birds during surveys was shown to have advantages over an analysis limited to the use of presence–absence data.

Introduction

Grey Fantails *Rhipidura albiscapa*, although small, are conspicuous and vocal when foraging throughout the year and are thus easily surveyed. In addition, they are widely distributed and occupy a range of habitats (Higgins *et al*. 2006). In the *New Atlas of Australian Birds* (Barrett *et al*. 2003), reporting rates (the frequency of reports with which a species is recorded during surveys) for the Grey Fantail were among the highest for any species in the Hunter Region of New South Wales (NSW), and were high throughout the year. It was unexpected when, in the winter of 2006, I found that Grey Fantails were scarce at Green Wattle Creek (GWC) (now known as the Butterwick Crown Lands Reserve), an area of woodland that I regularly surveyed near Paterson in the central Hunter Valley. This finding triggered a detailed analysis of the long-term trends in numbers of Grey Fantails, which is the focus of this paper.

In order to understand these observations, I analysed data on the monthly abundance of Grey Fantails at GWC, where I had conducted monthly surveys from 1996 to 2009. I also analysed abundance data from two nearby farms, surveyed

quarterly over the same period, to determine long-term trends in the abundance of Grey Fantails in the Paterson area more generally. A summary of the avian populations at these three locations has been published previously (see Newman 2007 for Butterwick; Newman & Lindsey 2008 for Warakeila; Newman 2009 for GWC). However, the previous analyses, which involved all bird species present, were much less detailed than the following analysis of populations of Grey Fantails. A second purpose of the analysis here was to examine whether counts of birds during Atlas-type surveys provided better quantification of population change than simply recording the presence of species, which was the minimum, and frequently used, protocol for the *New Atlas of Australian Birds* (Barrett *et al.* 2003) and used in ongoing bird atlassing (see Birdata, available online at http://www.birdata.com.au/).

Methods

I conducted surveys at GWC, near Paterson, NSW (32°40′S, 151°39′E) (Newman 2009); at Butterwick (32°39′S, 151°39′E) (Newman 2007), a cattle property adjacent to GWC; and at Warakeila (32°15′S, 151°31′E) (Newman & Lindsey 2008), a cattle property near Eccleston, in the Allyn River Valley ~45 km north-west of GWC. At GWC, I conducted one survey a month for 165 consecutive months between April 1996 and December 2009. At Butterwick and Warakeila, I conducted surveys quarterly over the same period; I undertook a single survey within 21 days of the mid-point of January, April, July and October (a total of 55 surveys). The surveys at GWC and Butterwick began within 1 hour of sunrise. At Warakeila, because of the time required to travel to that location, surveys began 2 hours after sunrise. Two observers (MN, Ann Lindsey) conducted the surveys at Warakeila. Because total survey times varied, each taking between 3 and 5 hours, some surveys (particularly at Warakeila) were completed after avian activity had decreased in late morning, which may have had an adverse impact on detection rates, particularly in hot weather. As all surveys were conducted in the same manner, the data sets established at each location (e.g. Warakeila) were generated with a 'constant effort approach'.

Survey methods

Each survey involved two components: a fixed-route survey and a series of four, fixed-site surveys embedded along the fixed-route. The fixed-route and the locations of the fixed-sites for the GWC study area are shown in Figure 1; the routes of surveys at Butterwick and Warakeila can be found in Newman (2007) and Newman & Lindsey (2008), respectively. The durations of total surveys (i.e. fixed-route plus four fixed-sites) were typically 4 h at GWC, 3 h at Butterwick and 4.5 h at Warakeila; the time spent at the four fixed-sites was typically about one-third of the total survey time. The two components of the total survey, namely the fixed-route and the fixed-sites, both involve sampling an area of bird habitat; in the first instance by walking along a fixed-route linking the fixed-sites and secondly by walking around fixed-sites, which were a consistent area but varied in shape (square or rectangular in this study). Five separate lists were compiled during each survey, one for the fixed-route and one for each of the four fixed-sites. In the rare event that the same bird was thought to have been recorded in both the fixed-route and a fixed-site (e.g. a bird flying into a fixed-site from the fixed-route, which ends at the perimeter of the fixed-site), it was preferentially assigned to the fixed-site list.

The surveys were established as part of the Birds Australia (now BirdLife Australia) Birds on Farms project, which involved recording the numbers of all birds seen and heard during surveys. This survey approach is also used in the BirdLife Australia Ongoing Atlas and is described in *Atlas News* **14** (Anon. 2010).

At each of the locations (e.g. GWC) the surveys were conducted in a consistent manner in order that within pragmatic limits every survey was performed in the same way (i.e. using the

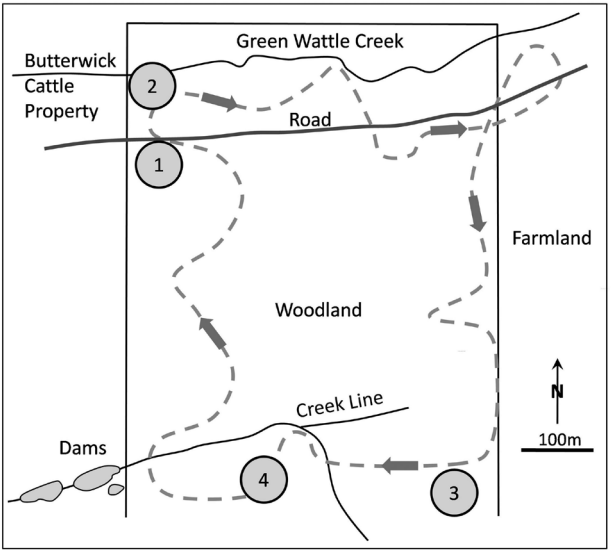

Figure 1. The locations of the fixed-sites (represented as circles 1–4) and the fixed-route at Green Wattle Creek.

same fixed-sites and the same fixed-route between sites). However, there were some minor changes, a consequence of habitat removal and fence erection by the landowners, which required minor modification to three fixed-sites (one at GWC and two at Warakeila) and the GWC fixed-route, but these adjustments did not result in any significant net change in the duration of the survey, area or type of habitat sampled.

Fixed-route. Birds were counted while the observer walked between the fixed-sites. The estimated length of the fixed-route (i.e. excluding the distance walked within the fixed-sites) was 2.5 km at GWC, 2.5 km at Butterwick and 4.5 km at Warakeila. Care was taken to avoid any double counting of birds, particularly when I crossed back over my path (see Figure 1). This was not difficult for Grey Fantails, which were predominantly encountered as dispersed individuals and small family groups, which did not appear to be moving through the area. The purpose of this component of the survey was to sample all bird species as opposed to achieving a constant sampling rate (i.e. more time was spent viewing a mixed foraging flock than moving through an area free of birds).

Fixed-sites. During each survey at GWC, Butterwick and Warakeila, all bird species were counted during a 20-min. period at each of the four fixed-sites located along the fixed-route. The area surveyed at each fixed-site was estimated to be 1 ha, as specified by the Birds on Farms project. Although these areas have not been measured precisely, none would exceed 1.25 ha.

The four fixed-sites at GWC were selected to represent the range of habitats present. As at 2009, the habitat of the fixed-sites, and the fixed-route at GWC, was primarily regrowth woodland with a closed canopy, except at fixed-site 4, where the woodland was more open. In 2009 the area had not been burnt for >20 years. Four tree species, typically >25 m tall, dominate the canopy: Forest Red Gum *Eucalyptus tereticornis*, Grey Gum *E. punctata*, Narrow-leaved Ironbark *E. crebra* and Spotted Gum *Corymbia maculata*, with a few White Mahogany *E. acmenoides* trees. Long-flowered Mistletoe *Dendrophthoe vitellina* is common in the woodland near sites 1 and 3. Lantana *Lantana camara* and Blackthorn *Bursaria spinosa* dominate the understorey throughout GWC, although the relative abundance and density vary throughout the study area. Green Wattle *Acacia irrorata* and the smaller shrubs *Ozothamnus*

diosimifolius and Prickly Beard-heath *Leucopogon juniperinus* are also present. Lantana ~1.5 m tall dominates the shrub layer at site 1. Site 2, although generally similar to site 1, borders Green Wattle Creek on one side, and the opposite bank adjoins a grassed oval used for equestrian events. At site 3, the understorey is dominated by extremely dense Blackthorn, typically >2 m tall. The open woodland of fixed-site 4 lacks a shrub layer, but has an extensive ground-cover of native grasses, including Blady Grass *Imperata cylindrica*, Kangaroo Grass *Themeda australis* and Tufted Hedgehog Grass *Echinopogon caespitosus*. The understorey and ground-cover increased at all four sites following the removal of cattle in 1996. Further details of habitat are provided for GWC and the farms at Butterwick and Warakeila in previous papers (Newman 2009, Newman 2007 and Newman & Lindsey 2008, respectively). Both Butterwick and Warakeila have 10–15% remnant vegetation, which is predominantly associated with creeklines at Butterwick.

Analysis of survey results

Reporting rates. Reporting rates are the frequency with which birds are recorded in surveys based on presence–absence data, and can be used to determine trends in the occurrence of birds in an area or over time. For a common species like the Grey Fantail, meaningful variations in reporting rate occur only when counts are conducted over relatively short periods of time and in small areas of habitat, as occurred when individual 1-ha fixed-sites were surveyed for 20 min. At each study area (GWC, Butterwick and Warakeila), reporting rates were calculated independently for each of the four fixed-sites. The annual reporting rates of individual fixed-sites were calculated from the monthly surveys at GWC and the quarterly surveys at Butterwick and Warakeila. Annual reporting rates for entire study areas were determined from monthly or quarterly surveys at all four fixed-sites (i.e. n = 48 at GWC and n = 16 at Butterwick and Warakeila). The statistical significance of differences in reporting rates was tested using the Chi-square test with Yates' Correction for comparisons involving one degree of freedom (Fowler & Cohen 1986).

Abundance. The results of both fixed-route and fixed-site surveys can also be analysed in terms of the numbers of Grey Fantails counted. Although comparisons can be made for variations in Grey Fantail abundance at the fixed-sites (number of birds/20-min. count), the numbers are small. Variations in abundance are amplified when birds are counted over longer periods and larger areas during the fixed-route component of a survey.

Caution must be exercised when comparing the results between the three study areas for two reasons. Firstly, there are differences in the habitat at the three locations, with GWC primarily woodland, and Butterwick and Warakeila cattle properties with only a small proportion of remnant native vegetation. Secondly, although the overall design of the surveys was similar in each of the studies, there were differences in the length of the fixed-routes, and surveys at Warakeila extended later into the day. During the following discussion, the emphasis is on comparing annual and quarterly trends in reporting rate and abundance between the three studies, rather than differences in the magnitudes of these measures.

For all three study areas, annual abundance was calculated as the mean number of Grey Fantails per survey for each survey method. At GWC, annual abundance was calculated from the monthly surveys; at Butterwick and Warakeila, it was calculated from the quarterly surveys. During 1996 only nine surveys were conducted at GWC and, although the results were similar to those obtained in 1997, they have been excluded from analysis of annual abundance to avoid biassing the results by calculating mean numbers on data for only part of a year.

Differences in abundance and reporting rates were calculated as the difference from the maximum value expressed as a percentage of the maximum value. The statistical significance of differences in abundance was evaluated using the F-test and the t-test (Fowler & Cohen 1986).

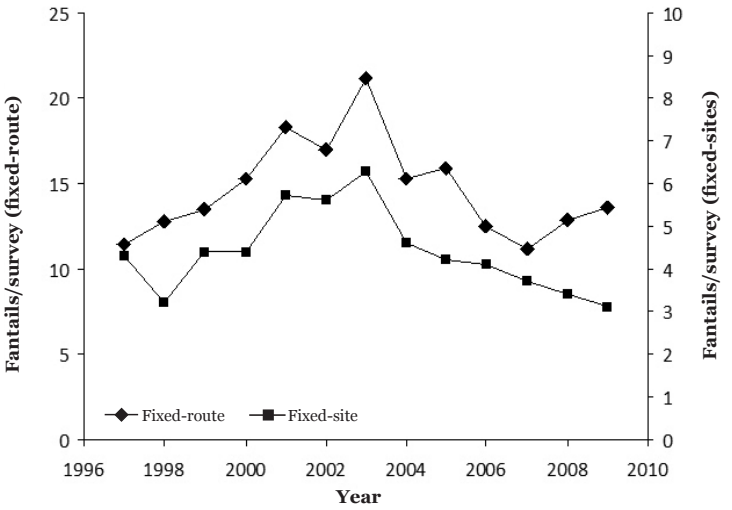

Figure 2. Annual abundance of Grey Fantails (mean number of Fantails per survey) from monthly surveys at Green Wattle Creek, 1997–2009, involving fixed-route counts (n = 12) and four combined fixed-site counts (n = 48).

Rainfall

To further examine possible explanations for the trends in abundance and reporting rates at the three study areas, I examined the correlation between abundance of Grey Fantails and the rainfall in the region for the current and the previous year (Fowler & Cohen 1986). I repeated this analysis with rolling average rainfall data for 5 years. Rainfall data for the period 1997–2009 from the Tocal Agricultural College, 10 km west of GWC and 40 km south of Warakeila, were used.

Results

Variation in annual abundance of Grey Fantails at GWC

The annual abundance of Grey Fantails (mean number of individuals per monthly survey) at GWC varied over the study period, with similar trends shown by the combined four fixed-site counts and the fixed-route count (Figure 2). In the first full year of the study (1997), abundance at GWC was comparatively low, with 11.4 birds/survey recorded in the fixed-route counts and 4.4 birds/survey in the combined fixed-site counts. Annual abundance reached a peak in 2003, with 21.2 and 6.3 birds/survey from the fixed-route and fixed-site counts, respectively, and then declined to levels similar to those at the start of the study. The average standard deviation of annual abundance was high (42%) because numbers of Grey Fantails vary seasonally (Figure 3). For the fixed-route counts there was a 47% difference in annual abundance between the maximum (21.2 birds/survey in 2003) and minimum (11.2 birds/survey in 2007). This difference was highly significant statistically (t = 3.9, P <0.01).

An important feature of the trends in annual abundance (Figure 2) is the similarity between variations for the fixed-site and fixed-route components. The only obvious difference was that in 2008 and 2009 the abundance of Grey Fantails increased

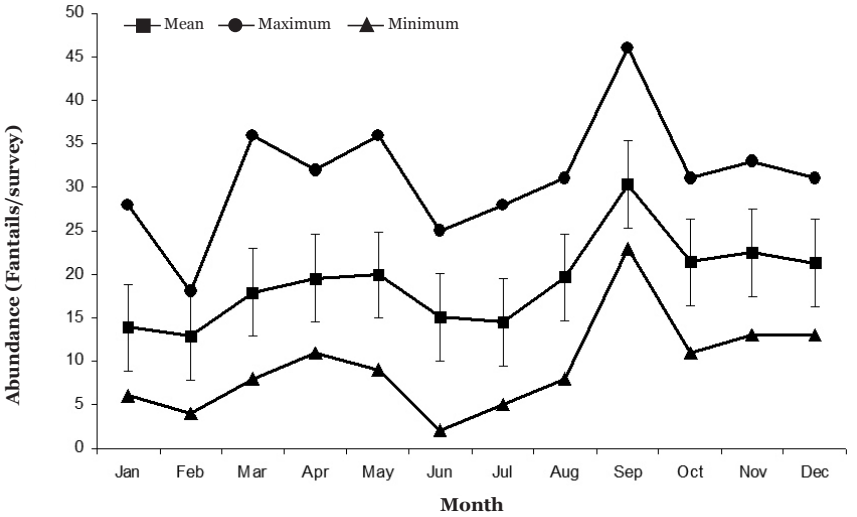

Figure 3. Monthly mean (error bars show 1 standard deviation), maximum and minimum numbers of Grey Fantails for fixed-route counts at Green Wattle Creek, 1997–2009.

in the fixed-route surveys, but continued to decline at the fixed-sites during those years. For the entire set of 165 surveys, the number of Grey Fantails recorded during the fixed-route counts was more than 3.3 times greater than in the fixed-site counts (which contributed only 23% of the number of individuals at GWC).

Variation in annual reporting rate at GWC

The trend in the annual reporting rate (Figure 4), which was determined from the combined fixed-site surveys (n = 48/annum), reached a peak in 2001 (81%) and then declined slightly through to 2003 (73%) before declining more rapidly through to 2009 (52%, which was identical to the initial reporting rate from 1997). Differences in the contributions of individual fixed-sites to the combined reporting rate are presented in Figure 5. The trends in reporting rates are similar to those of annual abundance (compare Figures 2 and 4). Further, the difference between the maximum and minimum annual reporting rate was 36% (Figure 4), also similar to the difference between minimum and maximum annual abundance (see p. 61). The high level of agreement between these two different approaches to measuring annual population change enhances confidence in the validity of the trends observed. However, the difference between the maximum (81% in 2001) and minimum (52% in 1997, 2007, 2008 and 2009) reporting rate was not statistically significant ($\chi^2 = 2.61$, $P = 0.11$).

Variation in monthly abundance at GWC

The monthly mean, maximum and minimum numbers of Grey Fantails per survey for the fixed-route surveys at GWC are shown in Figure 3. The standard deviations are high because the figures are calculated over a period of 13 years, during which the annual population varied considerably (Figures 2, 4). The trends in monthly

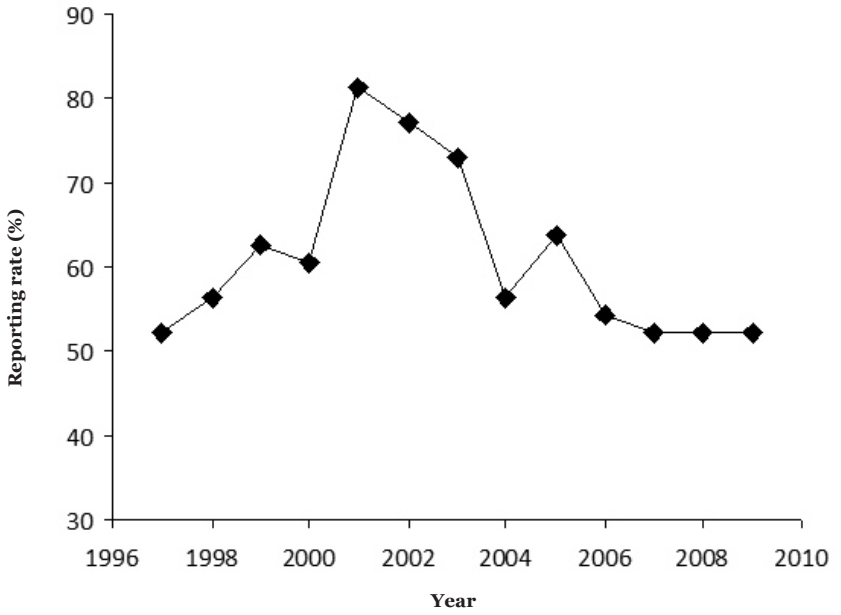

Figure 4. Annual reporting rate of Grey Fantails from monthly fixed-site counts (four fixed-site counts per month; n = 48) at Green Wattle Creek, 1997–2009.

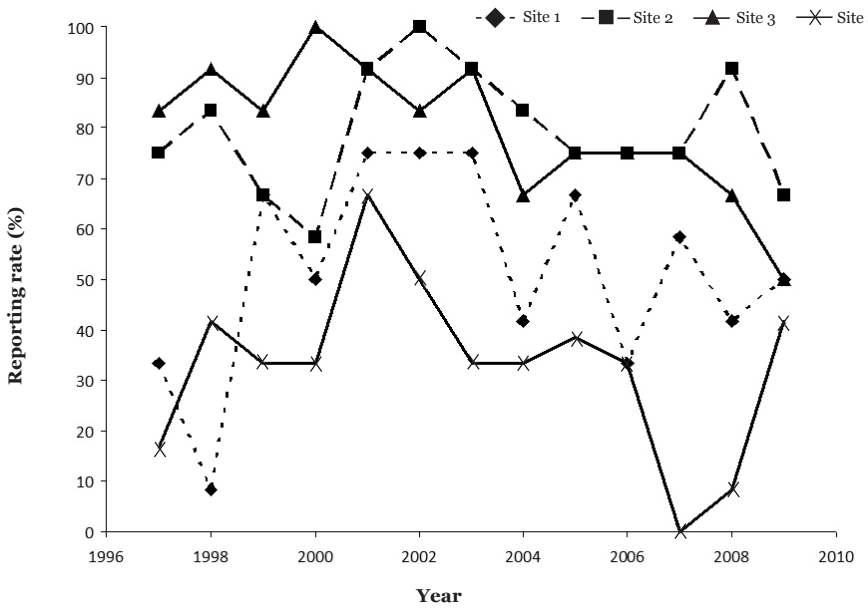

Figure 5. Annual reporting rate of Grey Fantails at the four fixed-sites at Green Wattle Creek, 1997–2009.

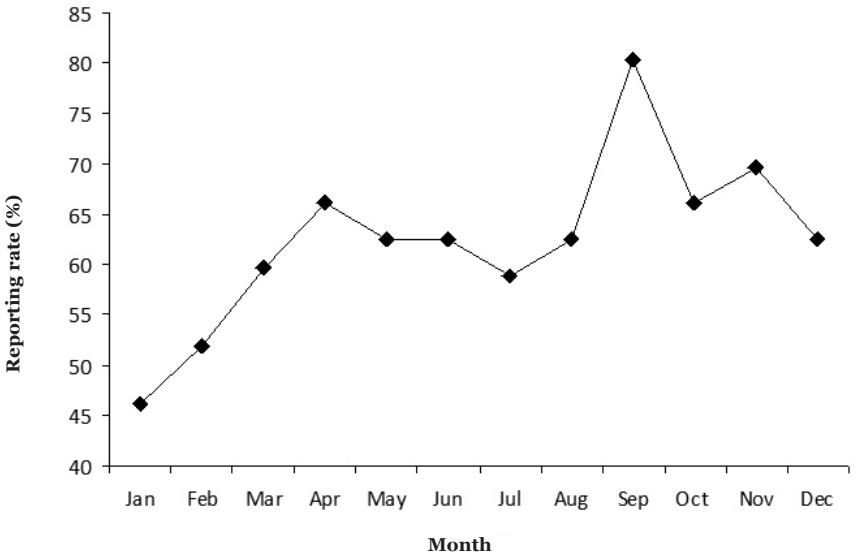

Figure 6. Monthly reporting rates for Grey Fantails at Green Wattle Creek, 1997–2009. Reporting rates were calculated from fixed-site surveys at four sites each month; n = 52 over 13 years.

abundance (Figure 3) are similar to the trends shown in monthly reporting rates for the fixed-site surveys (Figure 6), although reporting rates provide less detail of seasonal variation.

Over a year, numbers of Grey Fantails are low in January–February, followed by a slight increase in autumn during March–May (Figure 3). Numbers decline during June–July (winter) before rising to a peak in September and stabilising at a relatively high level between October and December (which is the breeding season: Stuart 2009), then decline again to the low numbers of January–February. These trends are exaggerated in the maximum numbers.

Variation in abundance in June and November

The mean abundance of Grey Fantails recorded during June–July (Figure 3) is ~65% of that observed during the breeding season, in October–December. Although this could be explained by the mortality of resident birds between the breeding season and June–July, particularly juveniles, inspection of the increased range of variation in the maximum and minimum numbers for the winter months suggests a more complex situation than indicated by the mean values. This is confirmed by the comparison of the annual variation in the June and November monthly counts (Figure 7).

The number of Grey Fantails recorded during fixed-route counts in June increased from 11 birds in 1997 to 20 in 2001, and then remained stable at 9–13 birds between 2002 and 2005 (Figure 7). There was then a dramatic decline in 2006, when just two Fantails were recorded, the lowest recorded in any survey. In 2007 and 2008 there was a gradual increase to the lower end of the usual range for June, but numbers

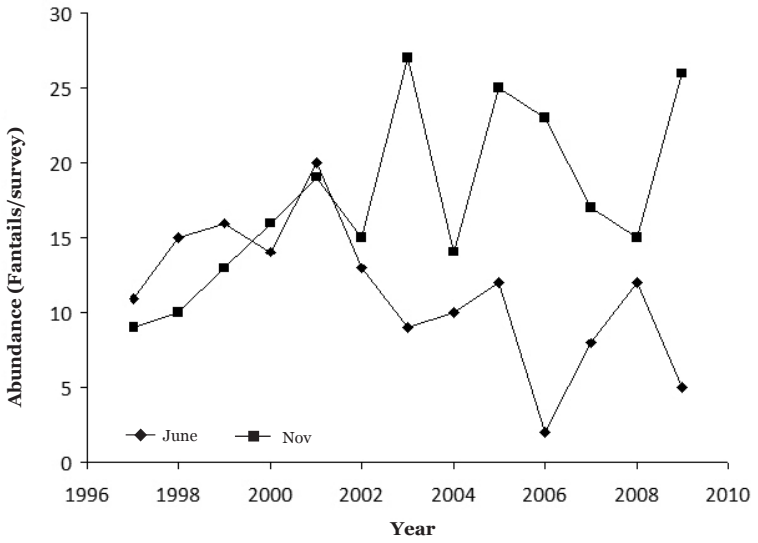

Figure 7. Abundance of Grey Fantails at Green Wattle Creek recorded during fixed-route counts in June and November, 1997–2009.

were low again in 2009. The low count in 2006 cannot be dismissed as an abnormal count, for instance as a consequence of adverse survey conditions, because the May and July counts for 2006 were also the lowest and second lowest recorded for those months, respectively.

In some respects the trend for the June counts shown in Figure 7 resembles the variations in annual abundance and annual reporting rates (Figures 2, 4). However, the magnitude of variation is much greater, and the decline in abundance started after 2001, which is 2 years earlier than the 2003 peak in annual abundance (see Figure 2).

For comparison, the variations in numbers of Grey Fantails in November, which are typical of the October–December breeding period, are also shown in Figure 7. The trends are different from the data for June, and numbers were not anomalously low in 2006 and, although some fluctuation occurred, there was no evidence of an overall decline.

Comparison of the fixed-sites

The four fixed-sites at GWC sample a range of woodland habitat types, and the monthly reporting rates of Grey Fantails at each of the sites are shown in Figure 8. At sites 2 and 3, which were characterised by the presence of mature trees and a dense understorey (Newman 2009; see Methods), monthly reporting rates were similar, typically >50% and at least 80% in October–December, during the breeding period. The trends are broadly similar to those for the monthly abundance of Grey Fantails (Figure 3). At site 1, which differs from sites 2 and 3 mainly in having an understorey that is less dense and less diverse, reporting rates were slightly lower

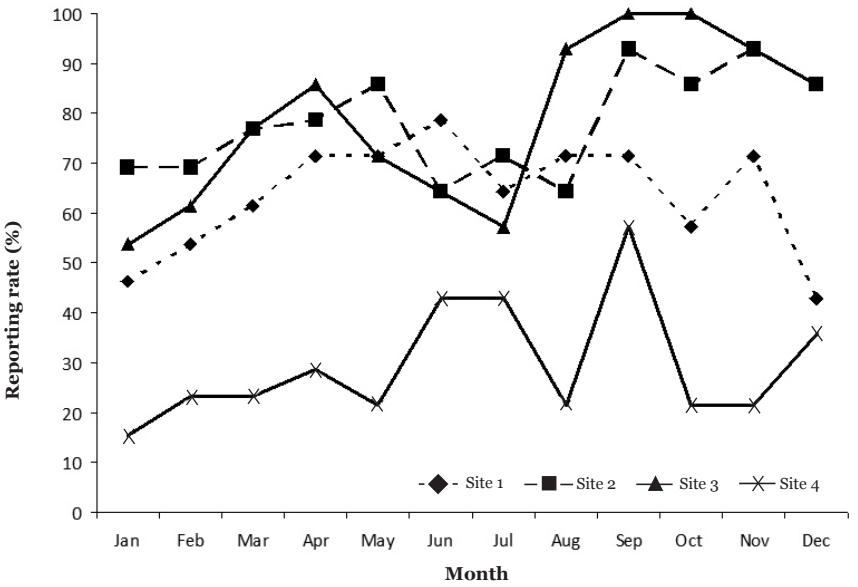

Figure 8. Monthly reporting rates of Grey Fantails at the fixed-sites at Green Wattle Creek, 1997–2009.

than at sites 2 and 3, particularly between August and December, when Grey Fantails were most abundant at GWC (Figure 3). In contrast, the monthly reporting rates at site 4 were much lower throughout the year, being ≤ 40% in all months except in September.

The trends in annual reporting rate at site 4, and the magnitude of changes over time, also indicate that site 4 is different from the other three sites (Figure 5). Annual reporting rates at site 4 were on average much lower than those at the other three sites, which were all similar. Sites 1, 2 and 3 all showed peak reporting rates during the period 2000 to 2003, followed by a decline and levelling off at 64% (on average) between 2007 and 2009. In contrast, although site 4 had a similar peak in 2001, the subsequent decline was greater, and no Grey Fantails were recorded at this site in 2007 (the only instance in which the species was not recorded at a specific fixed-site for an entire year), and few were recorded in 2008. It is interesting that the absence from site 4 occurred after the decline in the winter of 2006, which affected the entire GWC woodland in that year (Figure 7).

Comparison of GWC and Butterwick and Warakeila farms

The trends in annual abundance at GWC and the two farms at Butterwick and Warakeila were generally similar (Figure 9). The comparison of abundance between the three locations is based on the total numbers of Grey Fantails observed in the combined fixed-route and fixed-site counts (i.e. the total survey count). It was necessary to make this change in the basis of comparison because at the Butterwick and Warakeila farms the fixed-sites preferentially sampled patches of remnant vegetation, where most of the birds were recorded. Hence Grey Fantails were under-represented in the fixed-route counts. The similarity of the trends in abundance

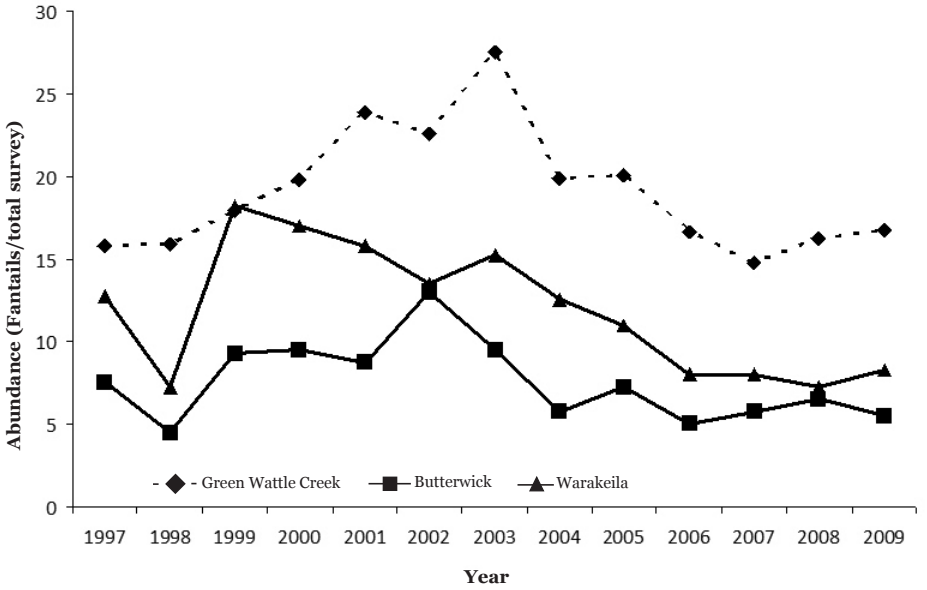

Figure 9. Annual abundance of Grey Fantails during total survey counts (i.e. combined fixed-route and fixed-site surveys for the three study locations); Green Wattle Creek (n = 12 monthly surveys), Butterwick (n = 4 quarterly surveys) and Warakeila (n = 4 quarterly surveys), 1997–2009.

found in the fixed-route and fixed-site surveys (Figure 2) provides justification for this combination. Grey Fantails were less abundant at Butterwick and Warakeila than at GWC, the difference being greater than can be explained on a pro-rata basis by variation in survey time between the study locations. The annual reporting rates from the fixed-site surveys at all three locations were also of similar magnitude and showed similar trends (Figure 10). However, the trends were more erratic at the two farms, a result attributed to the smaller sample sizes at Butterwick and Warakeila (n = 16; 4 fixed-sites per month × 4 months) compared with GWC (n = 48; 4 fixed-sites per month × 12 months).

The reporting rate for all fixed-site surveys (i.e. in all months) from 1997 to 2009 was slightly higher at Butterwick (67%, n = 208) than GWC (61%, n = 624) and Warakeila (58%, n = 208), but these differences were not statistically significant (χ^2_2= 1.37, P = 0.50).

Ratio of winter:spring abundance

The ratio of the total numbers of Grey Fantails in winter (June–July) to spring (October–November, which is in the October–December breeding season: Stuart 2009), are shown in Figure 11 for quarterly counts at the Butterwick and Warakeila farms. They are compared with the same ratio for GWC calculated from the counts for both months in each season. For both GWC and Butterwick, the average winter:spring ratio for the 13 years of the study (1997–2009) was 0.67 (i.e. numbers in winter were 67% of numbers in spring; n = 26 at GWC and n = 13 at Butterwick). The ratio was

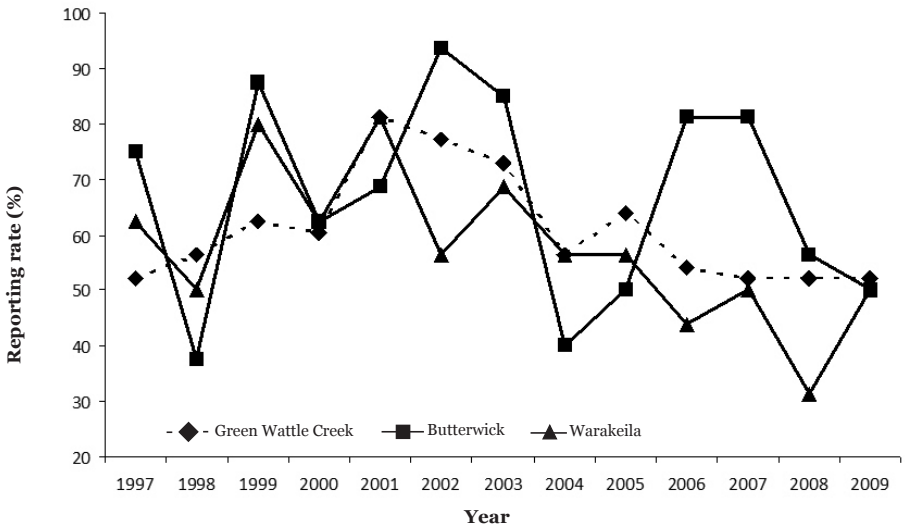

Figure 10. Annual reporting rate of Grey Fantails at Green Wattle Creek (n = 48), Butterwick (n = 16) and Warakeila (n = 16) from fixed-site surveys.

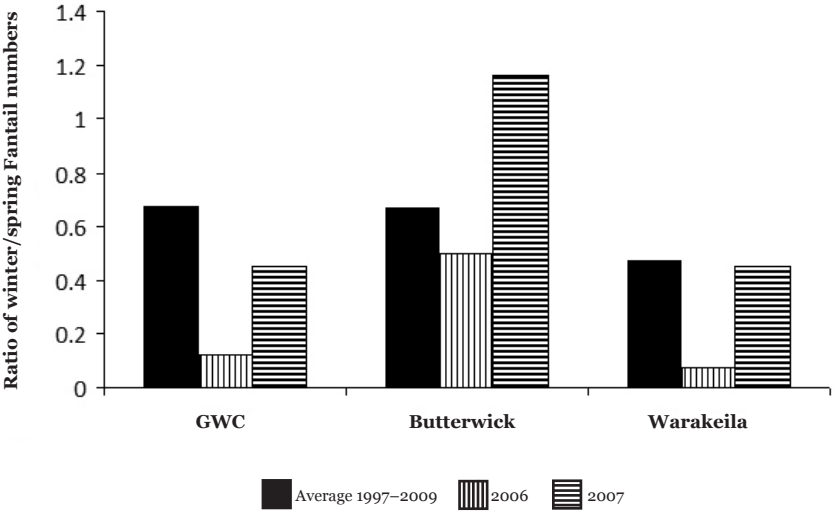

Figure 11. Comparison of numbers of Grey Fantails in winter and spring for total survey counts at Green Wattle Creek, Butterwick and Warakeila.

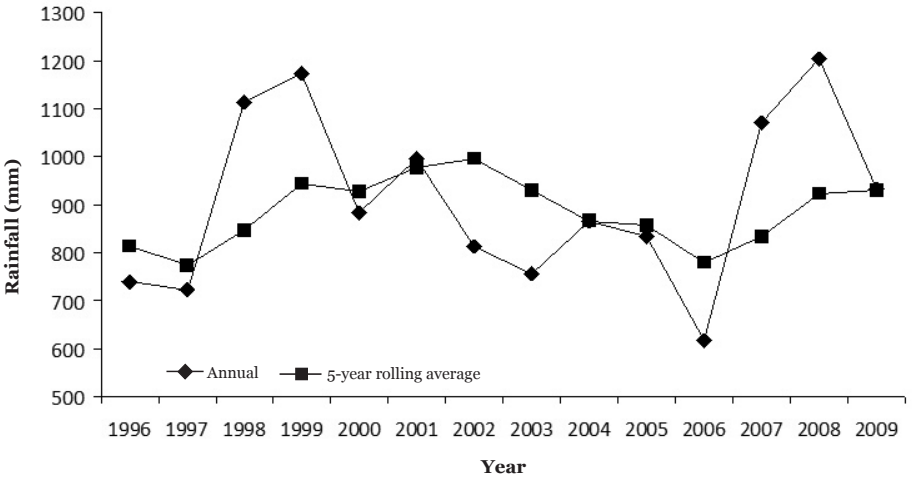

Figure 12. Annual rainfall at Tocal Agricultural College, in the Paterson area near the three study locations.

lower at Warakeila (0.47, $n = 13$). In 2006, at both GWC and Warakeila, the ratio fell to levels of ~0.1 as a consequence of the anomalously low numbers of Grey Fantails in June (Figure 7). By 2007 the ratios at these two locations had increased to 67% and 96% of the long-term average, respectively. The ratio at Butterwick in both 2006 and 2007 differed from that at GWC and Warakeila, with the ratio close to the long-term average in 2006, and nearly twice the long-term average in 2007.

Although the winter:spring ratio at Butterwick was below average in 2006, it was high compared with GWC and Warakeila in 2006. The ratio was also high in 2007, which indicates that Butterwick was less impacted by the scarceness of Grey Fantails in those winters.

Effects of rainfall

Variation in rainfall over the study period was examined as a possible explanation of the observed annual variation in the numbers of Grey Fantails. Average annual rainfall at the nearby Tocal Agricultural College showed a period of increasing rainfall from 1997 to 1999, followed by a period of higher average rainfall to 2002 (Figure 12). Rainfall was then lower until 2006, which was a particularly dry year with 618 mm, 69% of the average for 2000–09. After June 2007, rainfall returned to higher levels. The trends in rainfall match the variation in average annual abundance of Grey Fantails of the fixed-route counts at GWC (see Figure 2). Positive correlations were found between the annual rainfall of the current year and the previous year and annual abundance of Grey Fantails at GWC, but they were not statistically significant. However, when the analysis was repeated using rolling average levels over 5 years of annual rainfall, the results were statistically significant. The best correlation, which was highly significant, was with the previous year's 5-year rolling average rainfall ($t = 5.0$, $P < 0.01$, for which the correlation explained 70% of the variation ($r^2 = 0.70$).

Discussion

Trends in the populations of Grey Fantails at GWC

In a previous and preliminary evaluation, it was concluded that there was no difference in abundance and reporting rates of Grey Fantails at GWC when the two 6-year periods 1997–2002 and 2003–08 were compared (Newman 2009) and that the population of this species was stable. However, such a conclusion, based on comparing average measures over two periods, was misleading, because populations are constantly changing (Bounds *et al*. 2007) and the dynamics of this variation need to be considered. Interpretation of patterns of abundance of avian species can be further complicated when a local population comprises a combination of resident and migrant birds, for example, as found in the Wollongong district of NSW for the Yellow-faced Honeyeater *Lichenostomus chrysops* (Wood 2008). This complication affects the interpretation of trends in the occurrence of Grey Fantails at GWC, and necessitates that both annual and seasonal trends in populations are evaluated.

In the detailed evaluation presented here, it is shown that annual abundance and reporting rates of Grey Fantails at GWC increased between 1997 and 2000, with a peak between 2001 and 2003, and a decline between 2004 and 2009. The extent of the variation in population size was large, with the peak numbers in the fixed-route counts approximately double the minimum numbers in 1997 and 2007. This suggests that the population increases during the first half of the study 1997–2002 were cancelled by the decline in the second half 2003–08, explaining the conclusion by Newman (2009) that the size of the population was stable (i.e. the previous analysis compared the mean population sizes and did not consider the annual fluctuations).

The main features of the seasonal variation typically involved fairly stable numbers in the breeding season, between October and December (Figure 3). In June–July, numbers were ~70% of those of the breeding season. A sharp peak in September and a less-pronounced peak between March and May were attributed to birds migrating through the area. The low numbers of Grey Fantails in January–February may be a result of several factors: (1) movement of birds from GWC; (2) under-reporting because birds are less active during summer; (3) birds are heard less, and thus detected less, because of the deafening noise of cicadas (Hemiptera); (4) or some combination of these.

An explanation of the annual and seasonal trends in mean annual abundance must also explain the difference in the annual trends in the June and November numbers of Grey Fantails (Figure 7). Between 1997 and 2001 the trend was increasing in both months, but between 2002 and 2009 the numbers in June (winter) decreased and were always lower than the November counts (i.e. in the breeding season), which sustained the higher 2001 levels. This suggests that after 2001 a significant proportion of the population left GWC during winter. The extent of this exodus varied, from 93% in 2006, when only two Fantails remained, to 22% in 2008. Numbers of Grey Fantails in winter were also very low in 2009 (six birds).

Two alternative hypotheses are proposed as possible explanations of these trends. The first hypothesis involves a core population, which is resident throughout the year, supplemented at times by birds on passage during the spring and autumn migrations. Population trends for this hypothesis will primarily be driven by variations in

local conditions in the Hunter Region (e.g. rainfall and changes in the study-area habitat). The alternative hypothesis involves the possibility of the partial or complete replacement of the breeding-season population by individuals that have bred farther south. In this case, the population trends will be driven by a combination of local and external factors, which impact on both migrant populations when they are absent from the Hunter Region (e.g. for the population migrating north to winter in the Hunter Region, rainfall conditions in the area where it breeds will be important).

In the following sections the fit of these alternative hypotheses of the GWC population is examined against insights gained by comparison with monitoring studies at other locations in the Hunter Region (e.g. the Butterwick and Warakeila farms), rainfall, land management and habitat changes as well as insights provided by studies into the movements of Grey Fantails in eastern Australia.

Comparison with trends at other locations

Many aspects of the trends observed at the two farms were similar to those at GWC, suggesting that factors affecting the Grey Fantail population at GWC were having a wider effect across the Hunter Region. Such a conclusion is supported by the disappearance of Grey Fantails from two of four study sites west of Jerrys Plains, ~80 km north-west of GWC, between 2006 and 2008 (Tarrant 2008). At Jerrys Plains, which is drier than the sites of the present study, reporting rates of Grey Fantails were low, and Fantails appeared to be present only under favourable conditions and absent during drought.

As the very low numbers of Grey Fantails at GWC in June 2006 occurred during a period of extended drought, rainfall was an obvious parameter for investigation. However, differences in some aspects of the trends (e.g. the extent to which the winter population of Grey Fantails declined at the different locations) suggested that local features, such as differences in habitat between the three locations, were also important. For instance, at the Butterwick property all the fixed-sites were located adjacent to creeks, which buffer them from the factors adversely affecting the winter populations of Grey Fantails at GWC and Warakeila under conditions such as drought. This conclusion is reinforced by the anomalously high ratio at Butterwick in 2007 when Grey Fantails were more abundant in winter than during the spring breeding season (Figure 11). The fixed-sites on the farms selectively sampled the remnant vegetation favoured by Grey Fantails, which explains why reporting rates were similar at all three locations, but Grey Fantails were less abundant during the fixed-route counts at Butterwick and Warakeila compared with GWC.

Rainfall

There was a positive correlation between annual abundance of Grey Fantails at GWC and the Paterson area annual rainfall. The highest statistical significance occurred when the 5-year rolling average values were evaluated displaced by 1 year. This suggests that the Grey Fantail population will increase following a sequence of years with above-average rainfall and decline during periods of drought involving a sequence of years of below-average rainfall. In both instances there is a lag of 1 year before the full impact of changed conditions is apparent. However, the correlation explained only 70% of the variation, which suggests that although local annual

rainfall may be the dominant factor, other factors are also important. For instance, the counts at GWC in November (Figure 7) indicate that the increase in abundance in the first half of the study was sustained during the breeding season throughout the subsequent period of lower rainfall, including when exceptionally low numbers of Grey Fantails were observed in June 2006. Inspection of the monthly rainfall data for the local Paterson area showed that 2006 was characterised by abnormally low rainfall throughout the first half of the year compared with long-term averages, with each of the first 6 months experiencing less than the long-term average rainfall. This suggests that, in addition to variation in annual rainfall, the pattern and distribution of rainfall throughout the year may be critical. However, this does not explain why numbers of Grey Fantails in winter declined more at GWC and Warakeila than at Butterwick (Figure 11), which is addressed in the next section.

During 2006 much of south-eastern Australia experienced rainfall that was very much lower than average which, coupled with several years in the past decade with below-average rainfall (Australian Bureau of Meteorology 2012), may have impacted adversely on the number of Grey Fantails moving north after the breeding season. A failure in the breeding population in areas farther south would adversely affect both the number of birds migrating through GWC and the number wintering, assuming the second population hypothesis involving a winter influx of birds which have bred farther south. The post-2001 discrepancy in the trends in the winter (June) and breeding-season (November) counts (Figure 7) are consistent with the second hypothesis. Although the wintering population is diminished by conditions external to the Hunter Region, the breeding population (which has moved to winter north of the Hunter Region) is not similarly impacted, and numbers in the breeding season (which includes November) are sustained. However, as suggested in discussing the impact of local rainfall, it is also necessary to explain why the impact differed between locations in the Hunter Region (Figure 11).

Habitat and grazing

A factor potentially affecting the abundance of bird populations at GWC was the removal of cattle shortly after the study began in 1996. This resulted in a progressive increase in ground-cover and understorey. Grey Fantails favour forests and woodlands dominated by eucalypts with a shrub understorey that is dense to moderately dense and low to tall (Higgins *et al.* 2006). It is suggested that the increase in understorey vegetation in the 6 years following the removal of cattle, combined with increased rainfall (Figure 12), allowed the population of Grey Fantails breeding in the area to increase, presumably as a consequence of a combination of factors such as increased food, shelter and nest-site availability. There was a corresponding decline in the population of Speckled Warblers *Chthonicola sagittata*, a ground-feeding species, which was attributed to this change in vegetation structure (Newman 2009, 2011). Assuming the first population model involving a resident core population, I suggest that during the breeding season numbers of Grey Fantails at GWC were sustained throughout the period of decreased rainfall, and the decrease in abundance after 2002 is primarily associated with declines during the remainder of the year. I also suggest that new Grey Fantail territories in the previously grazed areas away from the creeks become unsuitable during winter, particularly under drought conditions, resulting in either the local dispersal, or even northward migration, of some breeding

birds from their territories after the breeding season.

At Warakeila, a continuous decline in numbers of Grey Fantails started in 1999, earlier than at the other study locations (Figure 9). This is attributed to ongoing clearing, particularly in the first half of the study, of remnant scrubby vegetation both at the fixed-sites and along the fixed-route, which provided habitat for Grey Fantails.

Examination of the winter:spring ratios of Grey Fantail numbers shows that winter populations were anomalously low in 2006, at both GWC and Warakeila. In marked contrast, however, the 2006 winter population at Butterwick was only slightly lower than the long-term average and, in 2007, the ratio was anomalously high; these results are supported by high reporting rates in 2006 and 2007 at this location (Figure 10). At Butterwick, the fixed-sites and most of the other remnant vegetation where Grey Fantails were recorded were either on or close to creeklines (Newman 2007). In contrast, two fixed-sites at GWC and one at Warakeila were away from creeks and so supported less mesic vegetation. On the basis that mesic vegetation is important (e.g. Palmer & Bennett 2006), these fixed-sites would be expected to be less suitable for Grey Fantails, particularly under drought conditions. The proposition that drier woodland is less stable habitat for Grey Fantails is supported by the lower reporting rate at GWC fixed-site 4 (Figures 5 and 8), which is also not close to semi-permanent water (the creek at the northern boundary of the GWC study area).

One of the fixed-sites (site 4) at GWC was in drier open woodland, which lacked an understorey of shrubs. Grey Fantails were less frequently recorded at this site, particularly under drought conditions. Indeed, this was the only fixed-site at GWC where none were recorded in an entire year (2007). This finding, which highlights the importance of understorey and mesic vegetation to Grey Fantails, is central to understanding the minor differences in the trends of abundance of Grey Fantails between the three locations. At GWC a combination of cattle removal during 1996 and a period of above-average rainfall resulted in increased understorey and ground-cover throughout most of the area surveyed (pers. obs.). The increased numbers of Grey Fantails during the first half of the study is attributed to this change. However, during the subsequent extended drought conditions, the number of Grey Fantails fell, particularly in winter. At Butterwick, where most of the habitat supporting Grey Fantails is along creeks, the numbers of birds in winter did not decline during the period of exceptionally low rainfall in 2006. The Warakeila farm differed from Butterwick in that some remnant woodland and fixed-sites were away from the creeks, and there was some ongoing clearing throughout the study. Consequently, the woodland areas tended to be drier and, as at GWC, apparently unsuitable for Fantails under drought conditions. The fact that, under drought conditions in the Hunter Region, Grey Fantails favour areas with mesic vegetation is consistent with both the proposed population hypotheses.

Movements

The movement of Grey Fantails along the eastern coastline of Australia is central to both of the population hypotheses proposed to explain the trends in seasonal abundance. There is strong evidence for long-range movement of Grey Fantails in eastern Australia based on atlas data (Griffioen & Clarke 2002), which positions my study area at the southern extremity of the core winter range of Fantails migrating

from south-eastern Australia. However, not all Grey Fantails migrate (Griffioen & Clarke 2002; Higgins *et al.* 2006). Griffioen & Clarke (2002, p. 106) also suggested that movements of Grey Fantails 'form a continuous flow throughout the year', which is consistent with the broad post-breeding peak between March and May in the present study. However, the September peak in abundance (Figure 3) indicates that the southward movement of Fantails through GWC is more synchronised than suggested by Griffioen & Clarke (2002). At all times of the year Grey Fantails were present as dispersed birds, and no flocks were observed moving through GWC. Consequently, the observed seasonal trends provide strong evidence that Grey Fantails pass through the Hunter Region on passage, but this is possible with both of the proposed population hypotheses.

Advantages of counting birds

I have attempted to explain the trends in both the annual and monthly abundance of Grey Fantails at GWC based on the numbers of birds counted in surveys. These trends at GWC are also consistent with the trends observed on the two farms at Butterwick and Warakeila. The use of a constant-effort survey approach involving the same observer(s), a combination of fixed-sites and a fixed-route survey, and a target species that is relatively easy to detect and occurs as dispersed individuals and pairs rather than flocks are all factors that allow a successful estimate of the numbers present.

Similar trends are also found when the same data are analysed as reporting rates describing the frequency of occurrence of Grey Fantails at the four fixed-sites, which are small samples of the area surveyed. In other studies, trends in reporting rates have been used as indicators of population change (Franklin 1999; Johnstone *et al.* 2000).

Thus both approaches provide a quantitative measure, which can be used as an indicator of changes in abundance, and hence of population change, at least for Grey Fantails. However, as already indicated, the differences in abundance (count numbers) are statistically significant whereas the corresponding reporting rates are not and therefore provide a less reliable basis for evaluating changes in Grey Fantail populations in my survey. Indeed, the annual reporting rate at GWC would have to fall to 38% (as opposed to the observed minimum of 52%: Figure 4) to be significantly different (P <0.01) from the peak value of 81%. Population densities are an important prerequisite for the assessment of regional and national population sizes. The generation of population densities was not an objective of this study but, at least for Grey Fantails, could be achieved with improved measurement of the size of the areas counted and a determination of Grey Fantail detection rates, which are considered to be high.

Birds Australia adopted the 2-ha 20-minute survey as its preferred method for the New Atlas of Australian Birds, initiated in 1998 (Barrett *et al.* 2003), and for ongoing surveys and monitoring. The method assumes that reporting rates for 2-ha surveys are a surrogate measure of changes in abundance. The correspondence between the annual trends of abundance of Grey Fantails and presence-based reporting rates at fixed-sites in this study provides support for this assumption. The trends in the annual reporting rates for the fixed-site counts at the two farms were more erratic

than for GWC, because the sample sizes were smaller and evaluation of trends in reporting rates rely heavily on the availability of large datasets. The results presented here suggest that for comparisons across four fixed-sites a monthly sampling frequency (GWC) is superior to quarterly sampling frequency (farms), which gives suboptimal results.

Conclusions

GWC supported Grey Fantails throughout the year, with the population in June–July (winter) typically ~70% of the population in October–December, the breeding season. Increases in abundance in September and March–May were attributed to movement of birds on southward and northward migrations, respectively. It was not possible to distinguish unambiguously between two population hypotheses, one involving a resident breeding population at GWC and the other involving the northward migration of the breeding population in winter, when it is replaced by a population that has migrated from breeding grounds in south-eastern Australia. However, the discrepancy between the June and November numbers provides circumstantial evidence for the second hypothesis involving two migrant populations.

Long-term trends in numbers of Grey Fantails were explained by a combination of changes in annual rainfall and seasonal rainfall patterns, combined with the impact of removing cattle from the study area. The increase in understorey vegetation following the removal of cattle is considered to be beneficial to Grey Fantails, particularly in the breeding season. This finding is in marked contrast with that for ground-foraging species such as the Speckled Warbler, which underwent a pronounced and sustained decline in numbers following the cessation of grazing (Newman 2010).

The Birds on Farms survey methods, involving counting birds during a fixed-route survey combined with four fixed-site counts, proved very effective in monitoring Grey Fantails and understanding the factors underlying variations in their annual and seasonal abundance. Populations of species like the Grey Fantail undergo cyclical trends in abundance, and comparison of average numbers over two periods of time can result in misleading conclusions.

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