Effect of rainfall on the occurrence and numbers of Red-browed Finches in the Lower Hunter near Paterson

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The role of annual rainfall on the population dynamics of Red-browed Finches *Neochmia temporalis* on a small farm near Paterson in the Lower Hunter region of NSW was evaluated for the period 1996 to 2013, inclusive. The analyses were based on quarterly surveys of 20-min duration at four 2-ha sites where presence and count data were recorded. Despite large interannual fluctuations in Reporting Rate (mean 30.0%, standard deviation 11.9%), the Red-browed Finch population demonstrated long-term stability. The study period overlapped with the seven-year "Millenium Drought".
A highly significant ($p<0.01$) correlation with annual rainfall lagged by one year explained ~38% of the interannual variation in annual Reporting Rate. Analysis of the count data indicated a parallel increase in the number of birds/survey ($p<0.05$) and an increase in group size with rainfall lagged by two years. These results demonstrate how the Red-browed Finch, a multi-brooding granivore with a large clutch size can respond opportunistically to advantageous climatic conditions.
Highly structured bird surveys with a quarterly sampling rate generated data with sufficient statistical power to provide information on species-specific responses to changes in environmental conditions. A preliminary analysis of data for four other species suggests that the approach has wider applicability.

INTRODUCTION

In this short paper, we present an analysis of interannual variation in the occurrence and numbers of Red-browed Finches *Neochmia temporalis* on a small farm near Paterson in the Lower Hunter Valley, NSW between 1996 and 2013. The Red-browed Finch was selected for the analysis because grassfinches are potentially capable of responding quickly to favourable climatic conditions.

The aim of this study was to see if the results of quarterly monitoring had sufficient statistical power to identify short-term fluctuations in the occurrence and abundance of birds, and whether these changes were explained by variations in rainfall. We also looked for evidence of long-term changes in status using both presence data (Reporting Rates) and count data (numbers of individuals). Although we focussed on Red-browed Finches in this study, we also did a preliminary analysis of data for four other species, Grey Fantail *Rhipidura albiscapa*, Superb Fairy-wren *Malurus cyaneus*, Yellow-faced Honeyeater *Caligavis chrysops* and Yellow Thornbill *Acanthiza nana*, to assess the wider applicability of our approach (presented in the **Appendix**).

METHODS

Quarterly surveys were undertaken between 1996 and 2013 inclusive at four survey sites on a small farm adjacent to Green Wattle Creek Road near Paterson in the Lower Hunter Valley in NSW. The sites all were located in remnant vegetation patches on the farm (**Figure 1**). Detailed habitat descriptions for each site are provided in Newman (2007). The standard Birdata 2ha-20min survey method was used (https://birdata.birdlife.org.au/home), and the numbers of individuals of each species were counted. All surveys were conducted in the mornings by the senior author.

Data from the four survey sites (16 surveys/annum) were assessed to calculate:

1. Annual Reporting Rates – the percentage of surveys in which a species was present,
2. Two measures of annual abundance:
   a. The mean number of individuals/survey, and
   b. The mean group size (i.e. the number of individuals/survey for those surveys in which the species was present), All analyses and plots were undertaken using DataGraph 5.3 software https://www.visualdatatools.com/DataGraph/. Statistical significance was assessed at 5% and 1% levels (Sokal & Rohlf 1995).

The following analyses were undertaken:

1. Linear and curvilinear regressions of the annual Reporting Rates.
2. Linear and curvilinear regressions of Reporting Rate against annual rainfall lagged by one to three years.
3. Linear regressions of the mean numbers of birds/survey against annual rainfall, and annual rainfall lagged by one to three years.
4. Linear regressions of the mean group size of birds/survey against annual rainfall, and annual rainfall lagged by one to three years.

The rainfall records of the nearby Tocal Agricultural College were used for the rainfall analysis. The rainfall patterns were complex and included an extended seven-year period of low rainfall between 2000 and 2006 (**Figure 2**), the so-called "Millennium Drought" (van Dijk *et al*. 2013).

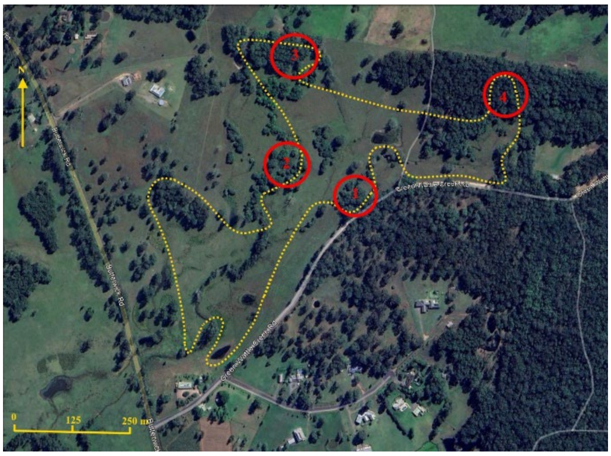

Figure 1. Locations of the 2-ha survey sites and the survey route conducted by walking from site 1 in a clockwise direction.

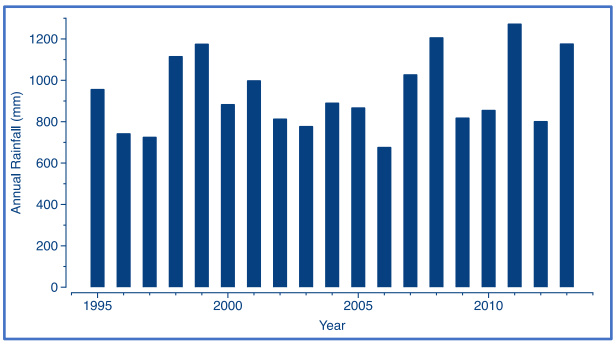

Figure 2. Annual rainfall (mm) for the Tocal Agricultural College near Paterson NSW: BOM for 1995-2013. (http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=139&p_display_type=dataFile&p_startYear=&p_c=&p_stn_num=061250).

RESULTS

Reporting Rate

There were large inter-annual variations in annual reporting rates (**Figure 3**). The slope of the linear regression line indicated a relative decrease in Reporting Rate/decade of 13.5%, but this result was not statistically significant. The low value of the Coefficient of Determination (r^2 = 0.044) indicates that the linear model explained <5% of the interannual variance present. The linear and curvilinear trends were almost identical (**Figure 3**).

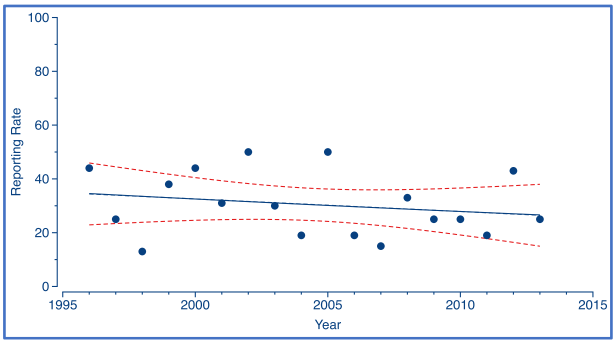

Figure 3. Red-browed Finch – Linear regression of annual Reporting Rates for the period 1996 to 2013, inclusive. The red dashed lines are the upper and lower 95% Confidence Limits for the linear regression. The regression was not statistically significant.

Seasonal Occurrence

Red-browed Finches were present throughout the year forming larger groups in winter (**Table 1**). The mean group size decreased in summer (January surveys) which coincided with the peak of the breeding season at Blackbutt Reserve, Newcastle (Todd 1997).

Table 1. Summary statistics for the seasonal occurrences of Red-browed Finches at a property in the Lower Hunter Valley NSW, 1996 – 2013, inclusive.

Metric	Summer	Autumn	Winter	Spring
Reporting Rate (%)	35.2	21.3	27.9	36.1
Mean group size	2.9	4.8	6.5	4.5
Standard Deviation of group size	3.8	4.8	7.0	3.6
Maximum number	13	15	25	16
Median number	2	2.5	4.5	4

Rainfall analysis

There was a highly significant correlation between annual Reporting Rate and annual rainfall lagged by one year (**Figure 4**). The high value of the correlation coefficient indicates that variations in annual rainfall explain ~38% of the interannual variation in annual Reporting Rate.

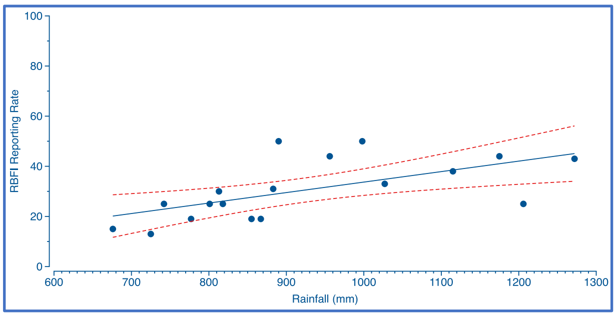

Figure 4. Red-browed Finch (RBFI) – Increasing linear trend in annual Reporting Rates and annual rainfall lagged by one year. The red dashed lines are the upper and lower 95% Confidence Limits for the linear regression. The trend was highly significant (p <0.01, r^2 = 0.379, r = 0.616, SIG).

A statistically significant linear correlation was identified between the mean number of birds/survey and annual rainfall (**Figure 5**) which accounted for ~24% of the interannual variance in the numbers of birds. The linear correlation between the annual mean group size of birds and annual rainfall lagged by two years approached statistical significance (**Figure 6**). No other significant or near-significant trends were found in the analyses examining the influence of annual rainfall on Red-browed Finch numbers over the study period.

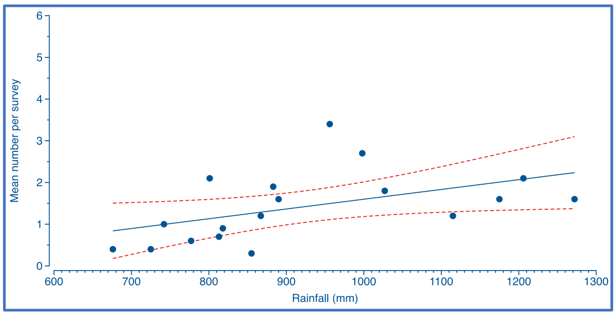

Figure 5. Red-browed Finch – linear regression between the mean number of individuals per survey and annual rainfall lagged by one year. The red dashed lines are the upper and lower 95% Confidence Limits for the linear regression. The trend was significant (0.05>p>0.01), r^2 = 0.238, r = 0.488, SIG).

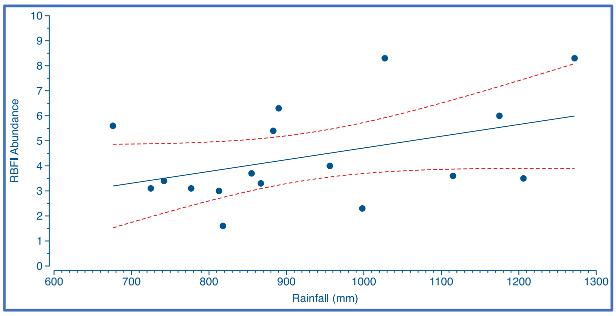

Figure 6. Red-browed Finch (RBFI) – linear regression between the mean group per survey and annual rainfall lagged by two years. The red dashed lines are the upper and lower 95% Confidence Limits for the linear regression. The regression approached significance (r = 0.428, critical value for r is 0.482).

DISCUSSION

Red-browed Finches nest in small colonies and can breed at any time of the year (Higgins *et al.* 2006), although this may not be the case in NSW (M. Todd pers. comm.). With up to three clutches annually, typically involving 4 or 5 eggs, their populations are capable of increasing more rapidly than most passerine species (Yom-Tov Yoram 1987). In central NSW, seeds are the major dietary item throughout the year, but may be supplemented by insects, particularly in the breeding season (Todd 1996). They are mainly sedentary and resident, with some local movements outside the breeding season (Higgins *et al.* 2006). Todd (1997) found that Red-browed Finches at Blackbutt Reserve, Newcastle in the Lower Hunter were largely sedentary.

Fluctuations in bird populations are determined by the balance between birth and mortality, driven by many factors. In the case of finches, which feed on seeds, fluctuations in food availability determine their lifestyle, which can vary between species and between locations (Newton 1972). In the case of the Red-browed Finch, a species considered to be relatively sedentary in the Hunter Region, breeding productivity would be expected to increase in response to climatic conditions (e.g. rainfall) that result in increased grass growth and seed availability, resulting in a population increase. In addition, these favourable conditions would be expected to increase temporarily the spread of locations Red-browed Finches can feed. Hence, favourable breeding conditions would be expected to result in both an increase in the number of survey sites at which finches are recorded (Reporting Rate) and the number of finches (Counts). Conversely, under drought conditions seed production and breeding success will decrease, and starvation will increase mortality.

Red-browed Finch population dynamics

There was no evidence of a decrease in the occurrence of Red-browed Finch at the location sampled during the study period. The statistically non-significant decrease in RR of 13%/decade is consistent with the "potential long-term decline" of the Red-browed Finch population in the Hunter Region *sensu* Williams (2020). The Red-browed Finch population was deemed stable based on the following metrics:

1. A low, non-significant rate of decadal decrease (13%).
2. A low Coefficient of Determination r^2 (0.044), consistent with the null hypothesis of no change in the population over the study period.
3. The longevity of the study (18 years), which was 10 times the estimated generation time of 1.8 years for the Red-browed Finch (Bird *et al*. 2020). Three generation times is generally considered sufficient (e.g. Garnett & Baker 2021), but Bennett *et al*. (2024) suggested that a longer period may be required in order to understand the recovery of species from extended climatic abnormalities such as the "Millenium Drought".

Fluctuations in annual rainfall explained much of the short-term variation in both presence (Reporting Rates) and abundance (numbers) of Red-Browed Finch. The more frequent occurrence in the year immediately following increased rainfall is attributed to an immediate breeding response to the increased rainfall. This results in an immediate population increase reflected in the next years' statistics, namely the statistically highly significant $p < 0.01$ increase in presence (Reporting Rate) and the near significant increase in abundance (number of birds/survey). Insectivores may respond less rapidly because it takes longer for insect populations to build up following such events compared with the rapid production of seed by grasses and other seed producers.

As the numbers of finches continued to build, flocks increased in size explaining the statistically significant relationship between group size and rainfall lagged by two years. Conversely, as rainfall decreased and food availability decreased, mortality increased, breeding success fell and the population decreased, resulting in decreased Reporting Rates and numbers of birds.

The long-term stability of the Red-browed Finch population in this study is attributed to the sound custodianship of the study location, which involved the retention of shelterbelts and riparian vegetation, and no removal of vegetation other than invasive weeds. A future challenge is to compare the results in this study with those of contemporaneous investigations elsewhere in the Lower Hunter involving comparable methodology at Green Wattle Creek (Newman & Cunningham 2014) and at East Seaham (Kendall 2023).

Efficacy of survey methodology

This analysis showed that quarterly 2-ha 20-min surveys at four sites had sufficient power to identify statistically significant trends in the population dynamics of a species present at an overall Annual Reporting Rate of 30%. Statistically significant trends were apparent in both presence data (Reporting Rates) and count data (measures of species abundance). This is consistent with the assumption that Reporting Rate is a surrogate measure of abundance, a pivotal assumption to the use of Reporting Rates to monitor bird populations throughout Australia.

The statistical power of the methodology was enhanced by the longevity of the study (18 years) that approximates 10 generations of the study species, and the highly structured sampling regime; i.e. one observer conducting replicated standardised surveys at regular intervals. Estimating the number of birds present during woodland surveys is challenging as it is prone to observer-specific error(s). These errors will tend to be systematic in single observer data, and less random than in multiple observer citizen science data sets. In this analysis, it was necessary to pool the seasonal results to provide sufficient observations (statistical power) for interannual comparison of Reporting Rates. Increasing the survey frequency from quarterly to monthly would have provided the statistical power necessary for a more sophisticated evaluation comparing seasonal differences in the species occurrence.

Future challenges

This analysis examined data from a single location, potentially raising questions concerning the relevance of the results at the broader, landscape scale to this and other woodland bird species. Birds are mobile, and for many species their occurrence at any site reflects their status in the local environment. Standardised surveys, such as used herein within a structured monitoring regime may provide early identification of population decreases. If these decreases are widespread, they may signal that the species meets the criteria for threatened species nomination. A more optimistic alternative is that the community will heed those early signals and implement land management practices that sustain bird populations and prevent them reaching Threatened Species criteria. The short-term challenge is to evaluate the existing data sets, while the long-term challenge is to establish an extended matrix of regularly monitored sites using standard methodologies to provide relevant data at landscape scales.

CONCLUSIONS

Seasonal and interannual fluctuations in the occurrence (Reporting Rates) and numbers (Abundance) of Red-browed Finch on a small farm near Paterson were explained by variations in annual rainfall. Despite these interannual fluctuations, the population was stable over an 18-year study period from 1996 – 2013, which overlapped with the seven-year "Millenium Drought". The methodology, which involved quarterly surveys of 20-min duration at four 2-ha sites has the potential to provide valuable insights into the population dynamics of other species for a modest investment of field work (15 hours/annum in this study). While these conclusions relate to a specific bird population, extension to an array of locations has the potential to provide landscape-scale trends in bird populations.

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APPENDIX

Other woodland bird species

Data for an additional four species, Grey Fantail *Rhipidura albiscapa*, Superb Fairy-wren *Malurus cyaneus*, Yellow-faced Honeyeater *Caligavis chrysops* and Yellow Thornbill *Acanthiza nana*, were analysed to assess the wider applicability of the data set. Statistically significant and near-significant trends were detected for three of these species including trends with annual rainfall lagged by two and three years for the Grey Fantail and Superb Fairy-wren. No trend was found for the Yellow-faced Honeyeater. It is beyond the scope of the present paper to give detailed context and explanations of these results. See **Table A1** for a summary of preliminary results.

Table A1. Statistically significant and near-significant trends in three additional species, Lower Hunter Valley NSW, 1996 – 2013, inclusive.

Species	**Trend**	**Statistical significance**
Grey Fantail	Positive - Abundance and rainfall lagged 2 years	Near-sig. at $p > 0.05$[1]
Superb Fairy-wren	Positive – Reporting Rate and rainfall unlagged Positive – Group size and rainfall lagged 3 years	Near-sig. at $p > 0.05$[1] Sig. $0.05 > p > 0.01$
Yellow Thornbill	Negative – Reporting Rate and rainfall unlagged Negative – Group size and rainfall unlagged	Sig. $0.05 > p > 0.01$ Near-sig. at $p > 0.05$[1]
Yellow-faced Honeyeater	None	

[1] The near-significant trends involve probabilities slightly exceeding the p=0.05 level.