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A method for investigating Rufous Scrub-birds using automated recording and rapid, semi-automated data analysis

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Calls made in a Rufous Scrub-bird *Atrichornis rufescens* territory were recorded for periods of about seven days using an automated recording unit. We developed a method using *Raven Pro* to scan these recordings for scrub-bird chipping calls for rapid analysis. We present a preliminary analysis of field data showing that the use of this analytical tool will facilitate investigations into how the singing behaviour of Rufous Scrub-birds varies daily and seasonally, knowledge that is important when designing population monitoring programs. Our study also suggests that an automated recording unit in combination with the *Raven Pro* identifier will provide a viable alternative to standard techniques for surveying sites for the presence of scrub-birds.

INTRODUCTION

The Rufous Scrub-bird *Atrichornis rufescens* is classified as endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and in the IUCN Red List, and as vulnerable under the New South Wales *Biodiversity Conservation Act 2017*. It occurs in five isolated, remnant populations in New South Wales and southern Queensland (Newman *et al.* 2014). The populations of both the northern (*A. r. rufescens*) and southern (*A. r. ferrieri*) subspecies are suspected to be in decline (Garnett *et al.* 2011).

It is difficult to see Rufous Scrub-birds, which mostly forage within and below the dense ground level vegetation in their territories (Ferrier 1984). Typically, the species' presence is confirmed by hearing a singing male. Females make a soft call which can only be heard if the listener is very close (Ferrier 1984). This makes it difficult to study the species and assess its status. All five Rufous Scrub-bird locations are designated as Key Biodiversity Areas (KBAs), with the scrub-bird in each case being the trigger species for the nomination (Dutson *et al.* 2009; BirdLife Australia 2017). Monitoring the status of trigger species is a requirement of the KBA process (Dutson *et al.* 2009) and there are active monitoring programs in all the scrub-bird KBAs (Newman *et al.* 2014; Andren 2016; Stuart and Newman 2018; F. Hill, R. Jordan, S. Dixon and P. Redpath pers. comm.), which currently involve listening for singing males (Ferrier 1984; Newman and Stuart 2011; Newman *et al.* 2014; Andren 2016; Stuart and Newman 2018).

The Rufous Scrub-bird's vocal repertoire includes a variety of calls and mimicry (Gole and Newman 2010). The most distinctive call is known as a "chipping" song, involving 2–10+ single syllables delivered in rapid succession (Stuart *et al.* 2012). Other calls have been described by observers as "whistles", "seeps" and "thrips," and there is also a contact call (Ferrier 1984; Stuart *et al.* 2012). In principle, all the scrub-bird's calls can be used to detect its presence. However, in monitoring programs for Rufous Scrub-bird populations using teams of volunteers, only documentations of chipping calls are accepted as confirmed records (Newman *et al.* 2014; Stuart and Newman 2018). This is so because inexperienced surveyors sometimes struggle to differentiate the other scrub-bird calls from those of other species.

The design of effective monitoring programs for Rufous Scrub-birds using the chipping call thus requires an understanding of how often the birds utter this vocalization and how this varies during the day and throughout the year. For example, when visiting a known or former territory to establish its occupancy status, a key question is how long to wait before it can be confidently concluded that a territory is no longer occupied? Similarly, when searching for new territories it is important to know how much time should be spent in the target area. To make these determinations, information about the singing behaviour of individual scrub-birds is required. As their behaviour can be affected by the presence of people near their territory (Ferrier 1984; Stuart *et al.* 2012), a potential role for automated recording units (ARUs) is apparent. A preliminary investigation of ARUs in this context, involving manual post-field analysis of the recordings, appeared promising for Rufous Scrub-bird monitoring (Stuart *et al.* 2012).

The use of ARUs in bird monitoring programs is growing (*e.g.* see Zwart *et al.* 2014; Sidie-Slettedahl *et al.* 2015; Bluff 2016; Joshi *et al.* 2017). The advantages of using ARUs include removal of observer bias, more natural bird behaviour (when there is no human presence), reduced time and effort in data collection, and the enabling of prolonged monitoring programs at sites which are remote or otherwise difficult to access. However, analysis of the recordings made with an ARU is problematic. An option is to manually scan sonograms and detect the target species by ear, or by sight if the sonogram pattern of their song is sufficiently distinct. This is a time-consuming option, but all the above advantages of using an ARU are retained. An alternative is automated data analysis using various algorithms that in effect act as an electronic "recogniser" of the calls of the target species (Joshi *et al.* 2017 and references therein). However, generation of a reliable recogniser can be challenging, especially if the call or song has a high degree of variability. Most electronic recognisers have suffered from high error rates, as the result of a combination of false positives (misidentification of the target species) and false negatives (failure to detect the target species when it is present) (Joshi *et al.* 2017). A recent review concluded that computer recognition of bird species from their calls was mostly inadequate for practical application, but commented that species-specific methods will generally be more successful (Priyadarshani *et al.* 2018).

The chipping call of a Rufous Scrub-bird is readily recognisable as a sequence of evenly spaced signals when a sonagram is scanned visually (see Fig. 1 for an example). Thus, it seemed a good candidate for an approach involving species-specific computer recognition. The focus of the present study was therefore on optimising the detection of chipping calls in recordings made in a scrub-bird territory using an automatic recogniser, with the aim of facilitating long-term monitoring of known or suspected Rufous Scrub-bird territories.

METHODS

We made recordings in a known Rufous Scrub-bird territory at 1,305 m altitude in the Gloucester Tops, New South Wales (Stuart and Newman 2018). The exact location is confidential; it was within a study area of approximately 5 km radius, centred at 32º04'S, 151º34'E.

The ARU comprised a Wildlife Acoustics Inc. Song Meter™ model SM3 with two omnidirectional microphones. We placed it ~0.3 m above ground in a steel-mesh framed stand in the scrub-bird territory and programmed it to record in one-hour files from 30 minutes before dawn until 30 minutes after dusk. It had previously been established that scrub-birds in the Gloucester Tops did not call at night (Stuart *et al.* 2012). Usually we collected 7–8 days (80–90+ hours) of recordings per field trip; battery lifetime governed the amount of recording that could be accomplished on each trip.

We recorded the data on SD cards, and later transferred them to a computer and analysed them using *Raven Pro 1.5* software. We developed detection conditions for the chipping call as per *Raven* software protocols. The conditions identified for the Band Limited Energy Detector were: minimum frequency 3000 Hz, maximum frequency 6,400 Hz, minimum duration 1 sec, maximum duration 6 secs, minimum separation 1 sec, minimum occupancy 20%, SNR threshold 2 dB, block size 8 secs and hop size 2 secs. We found these conditions to be the optimal ones for rapid, semi-automated analysis of recordings.

False positive results, usually associated with overlapping calls of other species, could quickly be eliminated by manual vetting of the results from the initial electronic analysis. Vetting was facilitated by the characteristic appearance of Rufous Scrub-bird chipping calls (Fig. 1). To estimate the proportion of false negatives, we analysed three hours of recordings manually and compared the results from the manual and automated analyses. We selected the period for this analysis at random, except that it was chosen from a time when the scrub-bird was making many calls. We found that the scrub-bird made 460 chipping calls in that 3-hour period, of which 446 were detected by the software (3% false negatives). In the results presented below, no correction has been made to address the occurrence of 3% false negatives.

We analysed the recordings by noting the number of singing events per 20-minute period. We chose this length of period because, when walking at a rate of 1 km/h through a Rufous Scrub-bird territory (the recommended standard survey method *e.g.* see Newman *et al.* 2014), a surveyor has an approximately 20-minute window of opportunity to hear a scrub-bird, given that calls can be heard from 150 m away under favourable conditions (Ferrier 1984).

We exported the results into *Excel* for further processing. We logged each chipping call as a single singing event under the automated search protocol, regardless of how many syllables it had. To assess if rainfall affected the scrub-bird's singing behaviour, we obtained data for the Careys Peak weather station (Station 61413) from the Bureau of Meteorology website (www.bom.gov.au). This station is located at 1,430 m altitude in the Gloucester Tops and is approximately 10 km from the Rufous Scrub-bird territory under investigation.

RESULTS

Recordings

We investigated recordings from six 7-day periods for this study (Table 1). Each 7-day period involved 83–95 h of recording, and generated total file sizes of *c.* 30 Gigabytes. Two of the time periods (29 September to 5 October 2015 and 23 to 29 September 2016) were during what is believed to be the onset of the breeding season for Rufous Scrub-birds; the other periods were outside the breeding season.

In Tables 2–7, we show data for each of the six 7-day periods. In each table, we firstly indicate the duration of each day's recording and the number of 20-minute periods into which that recording period could be divided. We then present the number of 20-minute periods in which we detected any singing activity. Comparing the number of active (*i.e.* with singing) 20-minute periods to the total possible number of 20-minute periods is a simple, first-pass indicator of the detectability of the scrub-bird on a given day. For example, on 29 September 2015 (Table 2), the scrub-bird called in 34 of the 39 possible 20-minute pre-dawn to post-dusk periods. In contrast, on 22 February 2017 (Table 4), we only detected the bird singing in two of the 42 possible 20-minute periods. Using these two examples of singing

Table 1

Rufous Scrub-bird recordings used in this study.

Session	Start Date	Finish Date	Total hours recorded (h)	Total file size (GB)
1	29 Sep 2015	5 Oct 2015	95	30.1
2	23 Sep 2016	29 Sep 2016	89	31.7
3	16 Feb 2017	22 Feb 2017	83	26.7
4	17 Aug 2017	23 Aug 2017	87	27.1
5	16 April 2018	22 April 2018	92	29.4
6	24 June 2018	30 June 2018	91	29.5

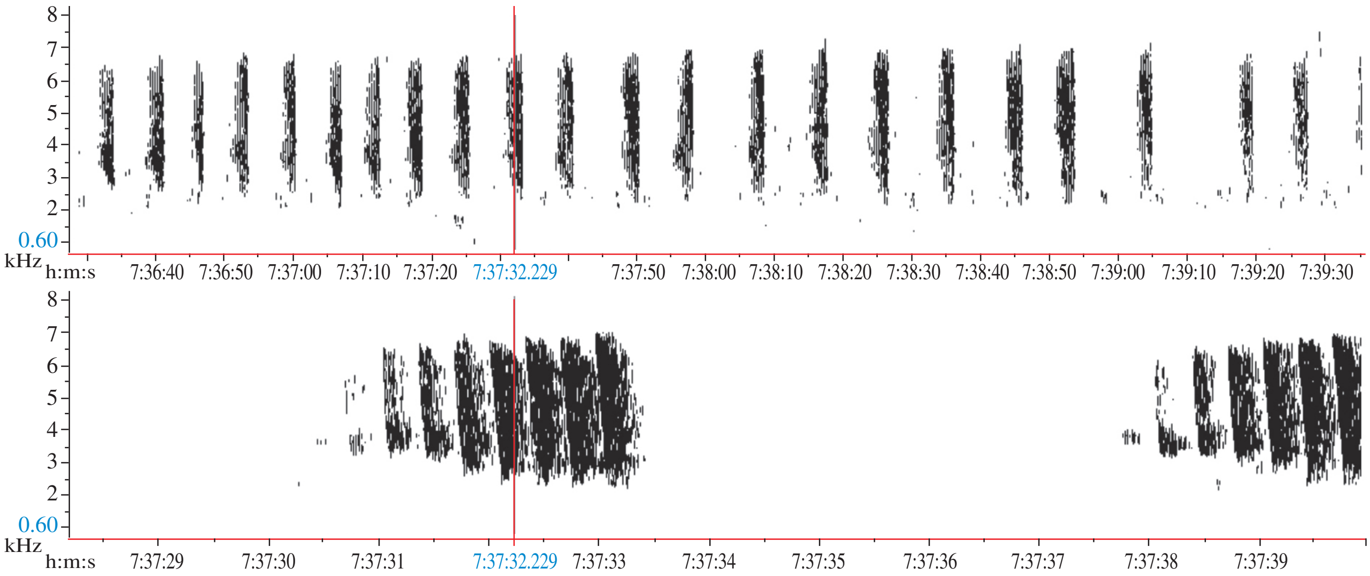


Figure 1. *Sonogram excerpt showing an example of a Rufous Scrub-bird's chipping song. Upper chart: a series of multiple chip calls. Lower chart: an expanded view showing two of the multiple chip calls.*

Table 2

Rufous Scrub-bird chipping call singing events 29 September to 5 October 2015.

	29 Sep	30 Sep	1 Oct	2 Oct	3 Oct	4 Oct	5 Oct
Length of recording (h)	13.3	13.3	13.3	13.4	13.4	13.4	13.5
No. of possible 20 min periods	39	40	40	40	40	40	40
No. of 20 min periods with activity	34	34	36	37	37	36	39
Total calls/day	1604	1643	1893	1669	1930	1568	1719
Maximum no. of calls in 20 min period	88	86	86	84	87	73	74
Minimum no. of calls in active 20 min periods	8	3	11	3	7	3	7
Median no. of calls in active 20 min periods	50	50	55	45	57	44	47
Careys Peak rainfall (mm)	0.2	0	2.6	0	0	0	0

Table 3

Rufous Scrub-bird chipping call singing events 23-29 September 2016.

	23 Sep	24 Sep	25 Sep	26 Sep	27 Sep	28 Sep	29 Sep[#]
Length of recording (h)	13.1	13.1	13.2	13.2	13.2	13.3	9.2
No. of possible 20 min periods	39	39	39	39	39	39	27
No. of 20 min periods with activity	34	38	34	37	32	37	23
Total calls/day	1481	1804	1170	1851	922	1887	796
Maximum no. of calls in 20 min period	74	92	80	82	81	96	81
Minimum no. of calls in active 20 min periods	1	2	1	5	1	5	2
Median no. of calls in active 20 min periods	51	50	31	46	29	53	33
Careys Peak rainfall (mm)	0.2	0.2	6.2	0.4	0	0	0

[#]recording stopped at 14:12 hrs

behaviour, the likelihood of establishing the bird's presence in a known territory would have been low in February 2017, but the detection probability in September 2015 would have been much higher. Similar analyses across all six of the tables suggest that the breeding season is the most reliable period for detecting a scrub-bird. In the other time periods investigated, there were sometimes days when the scrub-bird called often, but other days when it did not. For example, in April 2018 (Table 6) there were two dates, the 16th and 19th, when the scrub-bird called in 28 or 29 of the 39 possible 20-minute periods, but on all the other days in April 2018 it was silent most of the time.

Tables 2-7 also show the total number of chipping calls produced by the scrub-bird each day, the maximum number of calls it made in any 20-minute period and the median and minimum number of calls in 20-minute periods when the

Table 4

Rufous Scrub-bird chipping call singing events 16-22 February 2017.

	16 Feb	17 Feb	18 Feb	19 Feb	20 Feb	21 Feb	22 Feb
Length of recording (h)	14.2	14.1	Data missing	11.0	14.0	14.0	14.0
No. of possible 20 min periods	42	42		33	42	42	42
No. of 20 min periods with activity	9	12		2	8	4	2
Total calls/day	71	114		21	44	42	23
Maximum no. of calls in 20 min period	34	25		20	19	21	13
Minimum no. of calls in active 20 min periods	1	1		1	1	1	10
Median no. of calls in active 20 min periods	3	5		11	3	10	12
Careys Peak rainfall (mm)	0	0	4.0	1.0	0.6	0	0

Table 5

Rufous Scrub-bird chipping call singing events 17-23 August 2017.

	17 Aug	18 Aug	19 Aug	20 Aug	21 Aug	22 Aug	23 Aug
Length of recording (h)	12.0	12.0	12.0	12.1	12.1	12.1	12.2
No. of possible 20 min periods	36	36	36	36	36	36	36
No. of 20 min periods with activity	15	5	9	7	2	15	10
Total calls/day	270	37	76	61	11	291	168
Maximum no. of calls in 20 min period	60	20	22	22	10	52	65
Minimum no. of calls in active 20 min periods	2	1	1	1	1	2	2
Median no. of calls in active 20 min periods	12	6	8	3	6	11	12
Careys Peak rainfall (mm)	0	0	0	0	0	0	0

Table 6

Rufous Scrub-bird chipping call singing events 16-22 April 2018.

	16 Apr	17 Apr	18 Apr	19 Apr	20 Apr	21 Apr	22 Apr
Length of recording (h)	13.1	13.1	13.1	13.1	13.1	13.1	13.1
No. of possible 20 min periods	39	39	39	39	39	39	39
No. of 20 min periods with activity	29	2	10	28	11	9	10
Total calls/day	1170	473	157	879	137	176	197
Maximum no. of calls in 20 min period	82	46	33	74	47	34	63
Minimum no. of calls in active 20 min periods	13	2	2	1	1	3	2
Median no. of calls in active 20 min periods	39	19	14	33	8	19	12
Careys Peak rainfall (mm)	0	0	2.8	0.2	17.8	2.0	4.6

Table 7

Rufous Scrub-bird chipping call singing events 24-30 June 2018.

	24 June	25 June	26 June	27 June	28 June	29 June	30 June
Length of recording (h)	13.1	13.1	13.1	13.1	13.1	13.1	13.1
No. of possible 20 min periods	39	39	39	39	39	39	39
No. of 20 min periods with activity	8	3	18	27	10	15	12
Total calls/day	142	127	304	756	394	251	387
Maximum no. of calls in 20 min period	20	8	51	51	48	41	42
Minimum no. of calls in active 20 min periods	5	3	1	3	2	1	1
Median no. of calls in active 20 min periods	15	5	21	28	21	16	13
Careys Peak rainfall (mm)	0	0	0	0	0.6	2.0	0

Table 8

Proposed Rufous Scrub-bird detectability parameters.

Detectability rating	% of active periods	No. of calls/day	Median no. of calls in active periods
High	>70%	>1500	>40
Moderate	30-70%	500-1500	10-40
Low	<30%	<500	<10

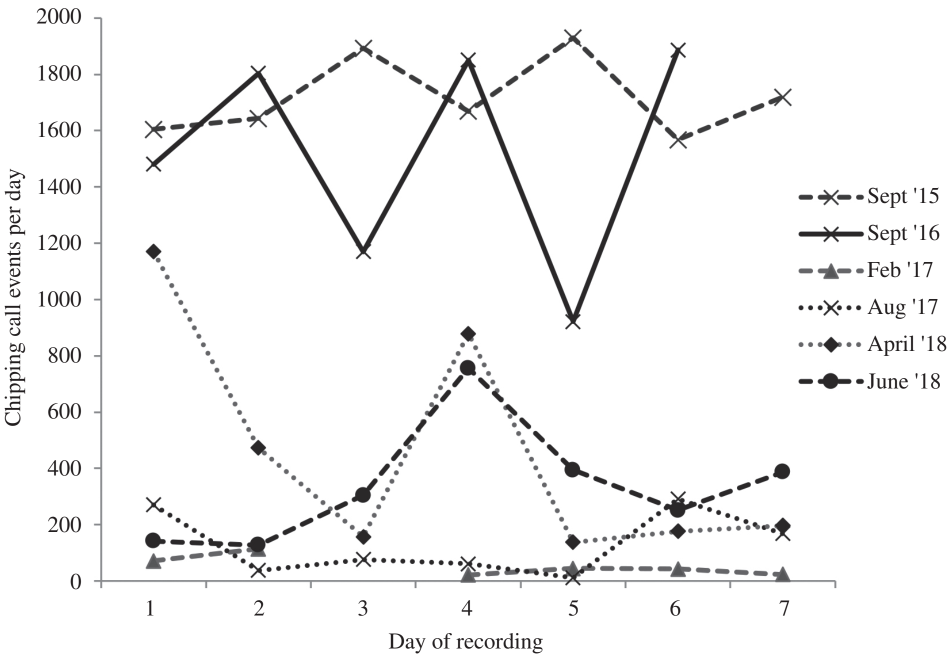


Figure 2. *The number of Rufous Scrub-bird chipping call events per day during six recording sessions.*

bird was actively singing. All these parameters are additional indicators of the detectability of the scrub-bird on any given day. For example, in the 2015 and 2016 breeding seasons (Tables 2 and 3), the scrub-bird usually produced more than 1,000 chipping calls each day, with medians of 40-50 calls per 20-minute period on most days. In periods of low singing activity, it usually still called at least a few times. Conversely, in February 2017 (Table 4) the scrub-bird mostly made fewer than 100 calls per day, with medians of just 3–12 calls per 20-minute period when active. The median numbers of calls per 20-minute active period were also low in August 2017 (Table 5), but more substantial in April and June 2018 (Tables 6 and 7).

In Tables 2-7 we also show the daily rainfall totals at the Careys Peak weather station. There was only one day of heavy rain in the six 7-day periods, on 20 April 2018 when 17.8 mm fell (Table 6). There was light rain (2-6 mm) on three other days in April 2018 (Table 6) and on 18 February 2017 (Table 4) and 29 June 2018 (Table 7). On all other dates on which we collected scrub-bird singing data there was either no rain or only light drizzle.

Number of chipping call events per day

The daily total numbers of chipping call events ("calls") are presented in Figure 2 (and in Tables 2-7). During the onset of the breeding season, the scrub-bird mostly uttered 1,500-2,000 calls per day. In September-October 2015 there was little daily variability, but greater variability was evident in the analogous period in the following year (23-29 September). Although four of the full days of recording in September 2016 each yielded more than 1,500 calls, two days (25 and 27 September) had fewer than 1,200 calls. The scrub-bird called less often in all the other periods investigated (Fig. 2); usually it produced fewer than 300 calls daily. In February 2017, the median was 43 calls per day, but in April and June 2018 the bird sometimes called more frequently, including producing 1,170 calls on 16 April (Table 6).

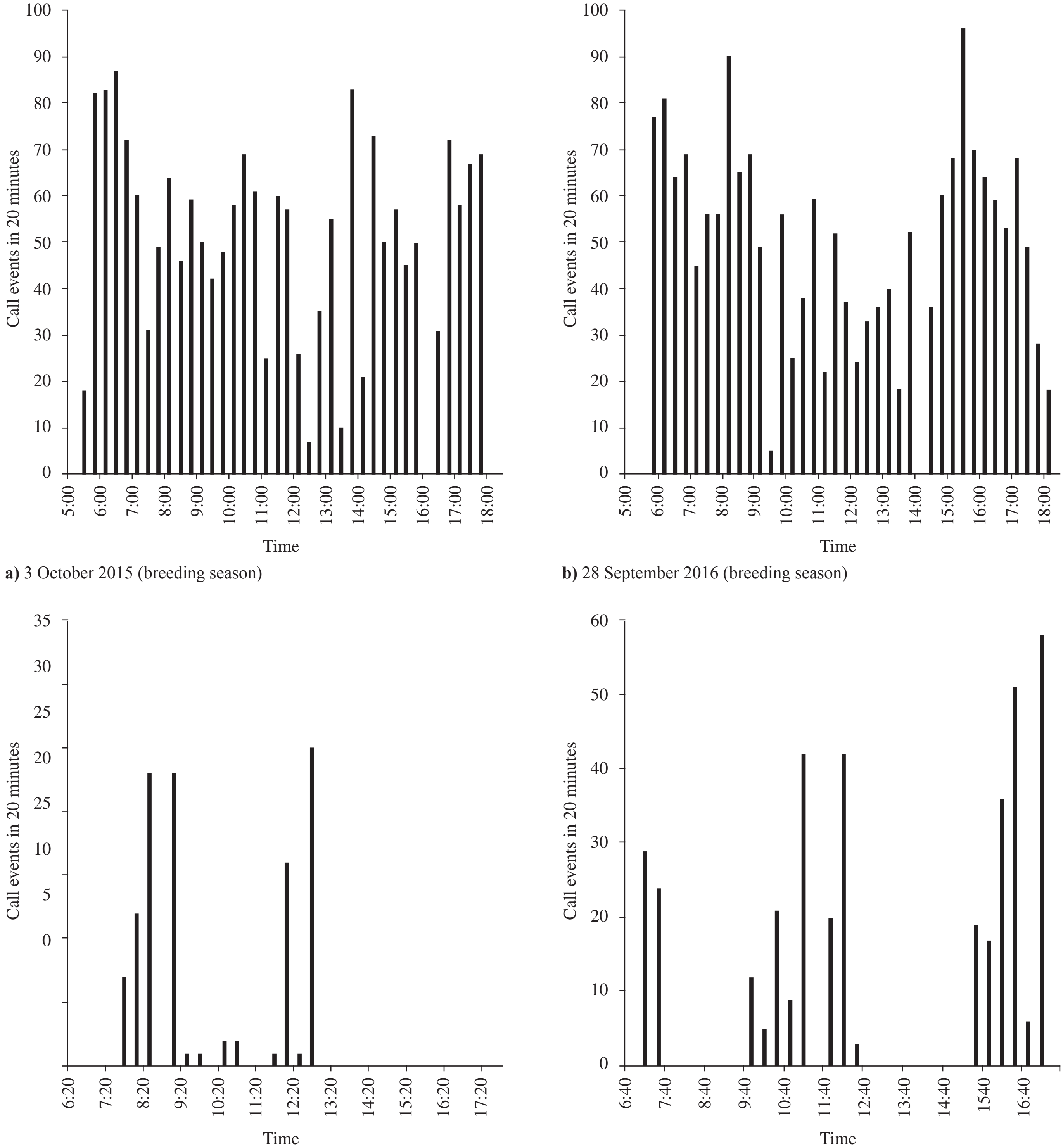
Daily and seasonal variability in chipping call events

Figure 3 shows four examples of single-day singing behaviour by the scrub-bird, presented in 20-minute segments. During the onset of the 2015 and 2016 breeding seasons, the bird sang throughout the day, with occasional breaks of 20-40 minutes (Figures 3a and 3b). The maximum number of calls in any 20-minute period ranged between 73 and 96 calls, with daily medians of 44–55 calls in 2015 (Table 2) and 29–53 calls in 2016 (Table 3). At the other times of the year investigated, the scrub-bird called far less frequently and with many long breaks. Details are summarised in Tables 4-7, whilst Figures 3c and 3d provide examples that illustrate the daily variability. Across all dates, there was considerable variability in the times of the day at which the bird called and in the maximum and median numbers of singing events each day. Also, on most days there were a considerable number of 20-minute periods when the bird did not produce any chipping calls. Often, less than 25% of the 20-minute periods in a day had any calling activity.

DISCUSSION

Daily and seasonal variability of calling

There are no breeding records for Rufous Scrub-birds in the Gloucester Tops, but individuals in more northerly populations had nests with eggs or young from late October onwards (Jackson 1911,1921; Chisholm 1951). This suggests that breeding activity in the northern populations, including territorial advertising by males, would have commenced in earnest at least one month earlier. Extrapolation to the Gloucester Tops suggests that the September-October recordings in 2015 and 2016 were probably made during the onset of the breeding season. There was a clear difference in singing behaviour by the Rufous Scrub-bird in September-October from other times of year. At those other times, it usually called infrequently and unpredictably, but in the breeding season it called very frequently and with only occasional short breaks.



a) 3 October 2015 (breeding season)

b) 28 September 2016 (breeding season)

c) 17 February 2017

d) 28 June 2018

Figure 3. *Examples of daily singing behaviour of a male Rufous Scrub-bird at its territory in the Gloucester Tops. Plots a) and b) are for what is believed to be the breeding season, plots c) and d) are in the non-breeding season.*

Daily variability appeared sometimes to be associated with weather conditions. For example, in April 2018 the scrub-bird called often on three days which had zero or very low rainfall (16-17 and 19 April) and far less often on the other four days when there was 2.0-17.8 mm daily rainfall (Table 6). Similarly, the scrub-bird made ~35% fewer calls on 25 September 2016 when 6.2 mm of rain fell than on the days immediately before and after that date (Table 3). However, its calling behaviour was unaffected on 1 October 2015 when 2.6 mm fell (Table 2). In spring 2016, the least number of calls in a day was on 27 September, a dry day (Table 3). However, these conclusions are tentative, as a much broader sample would be required to test statistically and convincingly for a possible weather effect.

Diurnal rhythmicity of calling

The ARU was programmed to record from 30 minutes before dawn until 30 minutes after dusk, as it had previously been established that scrub-birds in the Gloucester Tops did not call at night (Stuart *et al.* 2012). Results from the current study support those conclusions. There were never any scrub-bird chipping calls in the first 20-minute recording period of the day; calling usually began around dawn (or later). However, sometimes in spring there were a few calls in the final 20-minute recording period *i.e.* just after dusk.

Detectability of the Rufous Scrub-bird

Of the parameters that we investigated, three seem to have the greatest potential as indicators of seasonal and daily variability in Rufous Scrub-bird singing behaviour, namely the number of active 20-minute periods per day (as a ratio of the number of possible 20-minute periods), the total number of calls per day, and the median number of calls per active 20-minute period. When values for all these three parameters are high, a scrub-bird should be detected easily by a surveyor walking through its territory; when all three are low it most likely would escape detection. In Table 8 we suggest possible ranges for the three parameters as Rufous Scrub-bird singing indicators; in future studies, we plan to assess this proposal further.

Recordings from the 2015 and 2016 breeding seasons suggest a high probability that a surveyor would detect the scrub-bird while traversing its territory. In September-October 2015, there were very few 20-minute periods without any calling activity (Table 2) and none were consecutive. The scrub-bird's detectability in September 2016 would have been similarly high. Although there were sometimes fewer calls over the whole day then than in the 2015 season, there were very few 20-minute periods without any calling activity (Table 3), although two of the days had periods of *c.* 40 minutes without calling activity. Recordings obtained outside of the breeding season suggest that the detectability of the scrub-bird would be much reduced. There were many periods of inactivity, and when active the bird usually produced fewer calls per 20 minutes than it did in the breeding season (Tables 4–7).

Potential of the recording and analysis method as a tool to support monitoring

Analysis of automated recordings detected 97% of Rufous Scrub-bird chipping calls. Although these were results for a single territory, they suggest that using an ARU at a known or suspected Rufous Scrub-bird territory, with semi-automated analysis of the recordings, might quickly reveal whether the territory is occupied. A full day of recordings can be processed in less than 30 minutes, including manual vetting to eliminate false positives. Similarly, it may become possible to locate new scrub-bird territories by placing an ARU in areas of promising habitat. The effectiveness of this approach will depend on how far from the core of a territory the ARU can be placed. In the present study, the bounds of the core territory were known from prior studies (Stuart 2018) and the ARU was placed well inside the territory.

Future research directions

The results presented here are for a single scrub-bird territory. To optimise the design of Rufous Scrub-bird monitoring programs in the Gloucester Tops, it will be necessary to collect and analyse data from this territory for all seasons and to assess annual variability, and then compare these findings with results from several other territories.

Understanding the effectiveness of automated or semi-automated data analysis for recording of Rufous Scrub-birds from other parts of their population distribution is also required. There are known to be differences in the calls of the northern and southern subspecies (Ferrier 1984), so it may be necessary to develop a new electronic recogniser for some populations outside the Gloucester Tops.

The focus here has been on developing a tool that will help us to determine how often a Rufous Scrub-bird makes its characteristic chipping call, because that knowledge will underpin monitoring programs being used for the various populations. Eventually, the frequency of other call types should also be investigated, as that would further enhance the potential for ARUs/automated data analysis to be used in Rufous Scrub-bird population monitoring.

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