Development of a non-intrusive method for investigating the calling patterns of Rufous Scrub-birds

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Male Rufous Scrub-birds *Atrichornis rufescens* have loud characteristic calls which can be used to locate territories. The effectiveness of a monitoring program based on the detection of calling birds is dependent on good understandings of how their calling patterns vary with season, time of day, and local conditions. Since the presence of observers can affect a scrub-bird's behaviour, a non-intrusive method for investigating the calling patterns would have advantages. This study describes the development of a non-intrusive censusing method using a digital recording device programmed to record sonograms at a known or potential territory at pre-determined times, with the sonogram data analysed after they are later recovered from the instrument. Some progress has been made towards automated electronic analysis of the data using a "recogniser" developed from previously recorded "chipping" calls of a male Rufous Scrub-bird.

A male Rufous Scrub-bird was found to call very frequently in September, at the start of what is generally considered to be the breeding season. Its frequency of calling decreased outside the breeding season. The seasonal calling patterns for this scrub-bird were similar to those identified 30 years earlier.

Sonogram analysis of the characteristic chipping call of the Rufous Scrub-bird has shown that the first two syllables of a phrase have a narrower frequency range (less low frequency contribution) than the subsequent syllables, and the interval between the first and second syllables is greater than the intervals between each subsequent syllable. The numbers of syllables within individual phrases in a bout were often found to increase, from 1-3 syllables initially to 6-8 (or more) syllables later. This study has also confirmed previous findings that the individual syllables may be either downwardly or upwardly inflected, but that all the syllables in a phrase have the same inflection.

INTRODUCTION

The Rufous Scrub-bird *Atrichornis rufescens* is classified as Vulnerable under the New South Wales *Threatened Species Conservation Act 1995*. It has disappeared from lowland areas of its former range and it is now either extinct or very rare at altitudes below 600m (Ferrier 1984). Its modern range is restricted to five high altitude locations, extending from the Queensland/NSW Border Ranges south to the Barrington/Gloucester Tops area (Gole & Newman 2010). The southern sub-species *A. r. ferrieri* occurs in the Barrington Tops National Park (particularly the Gloucester Tops section of it).

The present Rufous Scrub-bird locations are high altitude "islands" which potentially will reduce in size or disappear as a consequence of climate change (Roderick & Stuart 2010, Watson 2010). To help develop appropriate conservation strategies and review their success, it is important that the Rufous Scrub-bird status be closely monitored. However, this poses problems as it is a cryptic skulking bird of dense undergrowth, which does not reliably respond to call playback.

Fortunately, male Rufous Scrub-birds are very vocal at times. Their loud penetrating calls can be heard from distances of >150m under favourable conditions (Ferrier 1984). Rufous Scrub-birds have a wide repertoire of calls and are renowned mimics. Their main song has been described as a "chipping" call. It consists of repeated phrases, each involving several one-note syllables. An effective method for monitoring Rufous Scrub-birds is to walk transects through likely habitat and listen for calling birds (Ferrier 1984, Ekert 2002, Newman & Stuart 2011). Greatest reliance is placed on records where the "chipping" call is

heard as this is call is readily recognised, having a resonant metallic quality which is easily distinguished from other species by experienced surveyors.

In order to maximise the usefulness of this survey method, good understandings are needed about how male Rufous Scrub-birds vary their calling patterns as a function of season, time of day, and local conditions. Ferrier (1984, 1985) developed important insights about this through an extensive series of transects through known territories. Under favourable conditions during the breeding season, Ferrier found the detection rate to exceed 80% (Ferrier 1984). He found that birds called in all months of the year, with detectability highest in the breeding season and favoured by low wind and high humidity. Jackson (1920) suggested that males called less frequently while the female was nesting, but Ferrier found the probability of males being heard calling was very high in the breeding season. Jackson spent long periods at individual Rufous Scrub-bird territories and his presence may have influenced the outcome.

Ferrier's study involved single pass transects through multiple Rufous Scrub-bird territories at different times of the year. He used a statistical approach to analyse the results, and he developed an empirical algorithm to predict the probability of hearing a scrub-bird during transects walked at 2.5 km/h through its territory. His intent was to develop a procedure which could be used to estimate the density of scrub-bird territories by conducting single visit transects. For instance, using his algorithm, if two territories are detected along a transect, under conditions for which the detection rate is 50%, it is predicted that there are four territories within 150m either side of that transect.

In 2010, through a program using volunteers and involving multiple as opposed to single transect surveys, we demonstrated similar densities of scrub-bird territories to those found by Ferrier in the Gloucester Tops (Newman & Stuart 2011). Because of differences both in the experience of the team and the transect sampling rates (1 km/h instead of 2.5 km/h), we were unable to relate Ferrier's algorithm to our results.

Since 2010, our objectives have become: (a) to determine whether previously known Rufous Scrub-bird territories were still occupied and (b) to determine any new territories. To achieve these objectives we continue to conduct surveys but when necessary spend extra time in the vicinity of known or suspected territories. The question is how much survey effort is required before we can conclude that a territory is no longer occupied?

Our preferred approach to resolving this question is to study intensively the calling pattern of a bird at a known territory and to apply this knowledge to the evaluation of other territories. We and others (Ferrier 1984) have noticed that the calling behaviour of scrub-birds can be affected by the presence of people in the vicinity of their territory, unless the observers are unobtrusive. This militates against using stationary observers to study the calling patterns; also, there is a finite (and relatively short) limit to how long observers are prepared to remain in position especially when weather conditions are unfavourable. Thus, a non-intrusive method for studying the calling pattern of Rufous Scrub-birds was required. This paper reports the development of such a method, involving capture and analysis of sonograms of calling Rufous Scrub-birds, and a comparison with intrusive transect-based census methods.

METHODS

A digital recording device (Wildlife Acoustics Inc. Song Meter™ model SM2) with two omnidirectional microphones was selected for the study. The Song Meter™ was programmed to record at fixed periods during the day, typically from just before dawn until after dusk, and sometimes to record overnight. For each session, the Song Meter™, encased within a steel mesh cage to help prevent damage, was installed at the edge of a calling node in a known Rufous Scrub-bird territory in the Gloucester Tops (32° 5±2' S, 151° 35±2' E) and left there for several days. It was placed 0.5-1m above ground, for example on a log or tree stump. **Figure 1** (see next page) shows the Song Meter™ installed at one such territory.

The data were recorded onto 8GB SD cards, which later were transferred to computer and analysed using Wildlife Acoustics Inc. Song Scope™ software. To date, most analysis has been by visual inspection of the Song Scope™ charts, with aural confirmation of suspected scrub-bird calls. Considerable effort has also gone towards developing an electronic "recogniser" whereby the chipping calls of the Rufous Scrub-bird will be able to be detected using the Song Scope™ software. To develop a "recogniser" using the Song Scope™ software, first a suite of confirmed calls are selected. The software analyses this suite, deconvoluting the signals to find an electronic pattern which is common to all of them. It is preferable to use calls recorded in the field to build the "recogniser" as this automatically takes into account instrument settings, microphone performance and electronic white noise. However, the varying quality of such recordings,

with their random background noise (due to wind, rain, other bird calls, etc.), militate against achieving a high quality (error free) recogniser.

Figure 1. The Song Meter™ installed at the Munro Hut Rufous Scrub-bird territory.

Nomenclature

In discussing the calling patterns of Rufous Scrub-birds, the following terms have been used, which in the main follow Ferrier's (1984) definitions:

Syllable: the single sound unit (e.g. "chip" or "seep").

Phrase: the collection of syllables that constitute one call event.

Bout: a period during which the bird utters the same type of phrase repetitively at intervals of <1 minute.

Calling Session: a period in which the bird delivers many bouts, with <10 minute intervals between bouts.

RESULTS AND DISCUSSION

Most of our effort focussed on a Rufous Scrub-bird territory located near the junction of the Careys Peak walking track and the track to the Munro Hut bushwalkers hut. This territory, belonging to what is sometimes referred to as the "Munro Hut scrub-bird", is conveniently accessed and the bird was known to be a reliable caller, at least in spring and summer, when the majority of our visits to the Gloucester Tops have occurred.

We recorded at the Munro Hut scrub-bird territory several times over 2011-2012, usually for periods of 2-3 days. Details are summarised in **Table 1**. We also installed the Song Meter™ for shorter periods (hours to 1-2 days) at three other known territories situated ~ 1km (Kerripit Road), ~3km (Gloucester Tops Road) and ~5km (Gloucester Falls) distance respectively from the Munro Hut scrub-bird. Overall, >300 hours of sonograms have been recorded, at four territories in the Gloucester Tops.

Table 1. Summary of the monitoring effort at Rufous Scrub-bird territories using the Song Meter™

Munro Hut	February 10-12 2011
Munro Hut	September 20-22 2011
Munro Hut	May 16-22 2012
Gloucester Falls	October 17 2011
Gloucester Tops Road	October 17-18 2011
Kerripit Road	October 19-20 2011

Chipping call of the Rufous Scrub-bird

The distinctive chipping call of the Rufous Scrub-bird involves a one-syllable sound repeated several times. Each call ("phrase") consists of between 2 and 8 (occasionally >8) syllables. In 2-syllable calls, the syllables seem almost identical. Multi-syllable calls have some different features. By way of example, **Figure 2** is a sonogram of a seven syllable phrase. It illustrates the following:

- The inflection of a syllable can be upwards or downwards (i.e. rising or descending); the direction of inflection is constant within a phrase (downward in **Figure 2**).
- The frequency range of each main syllable in multi-syllable calls is large (approximately 2.5kHz to 6.5kHz). This also is the case with the calls containing only 2-syllable calls discussed above.
- In multi-syllable calls the first two syllables have smaller frequency range than the subsequent syllables.
- The first syllable has only ~0.5kHz range. It is quite faint (and is unlikely to be heard unless the bird is very close).
- The interval between the first and second syllables is slightly greater than the intervals between each of the subsequent syllables.

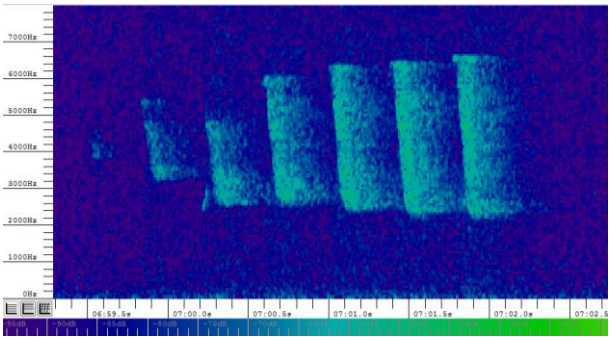

Figure 2. Example of a multi-syllable chipping call sonogram

During an extended observation of a calling male scrub-bird in the field, it was noted that when producing the first two syllables of the multi-syllable phrase, the bird had a horizontal stance and kept its head still. For the remaining syllables of the phrase it went into an upright stance with much more marked head movement as it called (AS pers. obs.).

In a typical calling bout, the Rufous Scrub-bird utters >20 multiple syllable phrases, at a rate usually between 3-5 phrases per minute. **Figure 3** is an excerpt from a sustained calling bout by the Munro Hut scrub-bird, illustrating the regular repetition of multi-syllable phrases (in this example, a mixture of 7-syllable and 8-syllable phrases) which occur during a calling bout. **Figure 4** shows an expanded view of part of the same sequence.

As indicated earlier, Ferrier (1984) found that the syllables of a phrase could be either ascending (upwardly inflected) or descending (downwardly inflected) but that the inflection did not change within an individual phrase. He also found that the southern subspecies uttered phrases of fewer syllables than the northern subspecies – with the latter at times delivering phrases of 18-20+ syllables. Our findings are in agreement; the Munro Hut scrub-bird typically delivered 4-8 syllable chipping calls, with 11 syllables being the maximum recorded to date.

Ferrier found very little variation to the number of syllables in the phrases within a bout. He reported the average standard deviation of the number of syllables in a bout to be 0.69. In contrast, the behaviour of the Munro Hut bird in the present study was quite different. Its bouts of chipping calls typically began with 1-3 syllable phrases, which steadily increased to 6-8 syllables (occasionally more) during the course of the bout. The limited data that we have obtained for other territories (e.g. **Table 1**) suggest this pattern of increasing number of syllables during a bout is common for Rufous Scrub-birds in the Gloucester Tops.

Sonograms of other Rufous Scrub-bird calls

Aside from mimicry of other species, the Rufous Scrub-bird utters several characteristic calls. In the main, these appear electronically as single syllable variants of the multiple chipping calls. The single "chip", "whistle" and "thrip" calls are all similar to one another, mainly varying in their frequency range. They differ audibly and electronically, but there is a gradation and to an extent it is a somewhat arbitrary decision to assign a call to one of these categories. The "seep" call is also single syllable, but it has a smaller frequency range (only ~1kHz, spanning 4.5-5.5kHz) and has a distinctive slope towards the higher frequency sounds in the latter part of the call (syllable). The Rufous Scrub-bird also delivers a contact call, which is a lower frequency (~2kHz) note which tails away noticeably in the sonogram. **Figure 5** shows some examples of "seep" and contact calls made by the Munro Hut scrub-bird.

Two birds in a territory

Ferrier (1984) noted a small number of examples of duetting by Rufous Scrub-birds, describing this as an interaction between a male and female bird and with the female uttering soft "tick" calls. We have noted some instances of this type of duetting during the intensive survey effort walking transects to locate calling scrub-birds.

An instance of two birds calling at the Munro Hut territory was recorded on the Song Meter™ and is presented as **Figure 6**. It shows one scrub-bird uttering single syllable calls and the second bird making 5-syllable calls. Note that, at 13 minutes and 26 seconds into the recording session, both scrub-birds called simultaneously. The behaviour differs from Ferrier's descriptions of duetting and possibly is an interaction between two male birds.

Calling patterns of the Munro Hut Rufous Scrub-bird in September 2011

The Song Meter™ was installed at the edge of the Munro Hut Rufous Scrub-bird territory shortly before 4pm on 20 September 2011. The scrub-bird resumed calling ~15 minutes after the intrusion into its territory. Initially the recordings were faint and the bird appeared to have moved to the other side of its territory. We analysed in detail the calling patterns from 4:30-5:30pm that afternoon, when the bird was closer to the Song Meter™. For comparison purposes we also analysed a one-hour period from 8:00am the following morning, when the bird was again close to the Song Meter™. **Table 2** summarises the results of the analysis while **Table 3** provides a more detailed breakdown.

In the 1-hour afternoon period, the scrub-bird delivered 245 song phrases during 12 calling bouts. The first bout was already underway at 4:30pm and the final bout continued after 5:30pm.

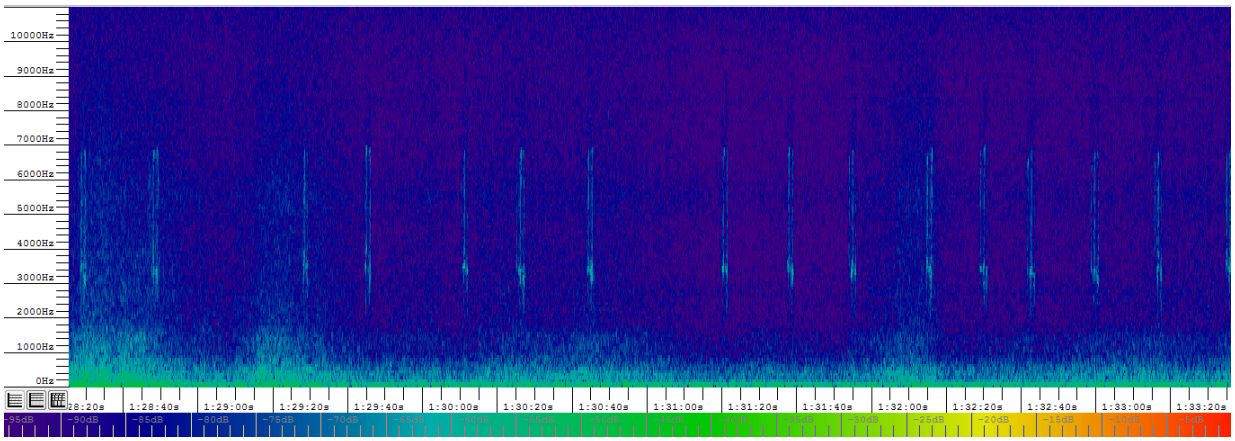

Figure 3. Extract from a calling bout: 7-syllable and 8-syllable chipping call sonograms at 15-20 second intervals.

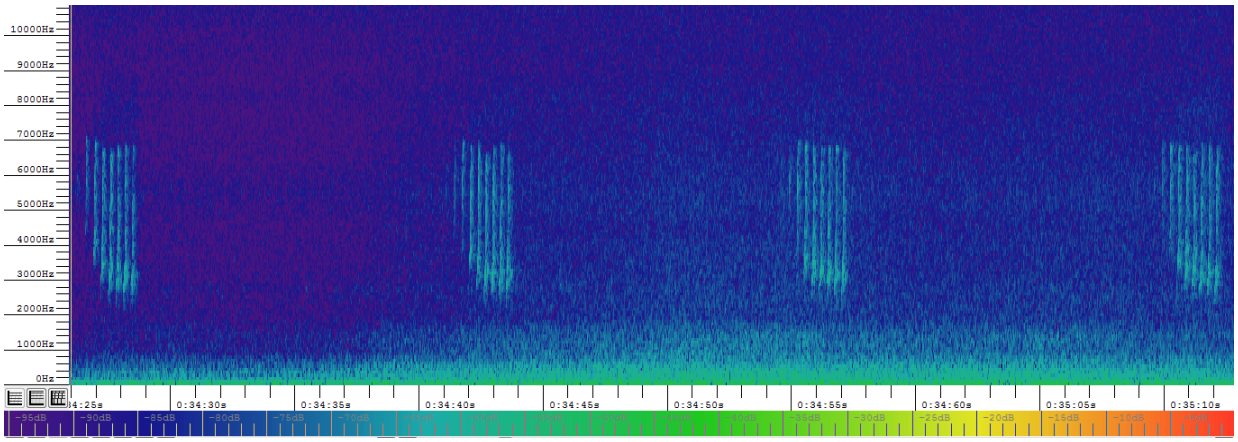

Figure 4. Detail from Figure 3: 7-syllable and 8-syllable chipping call sonograms at 15-20 second intervals.

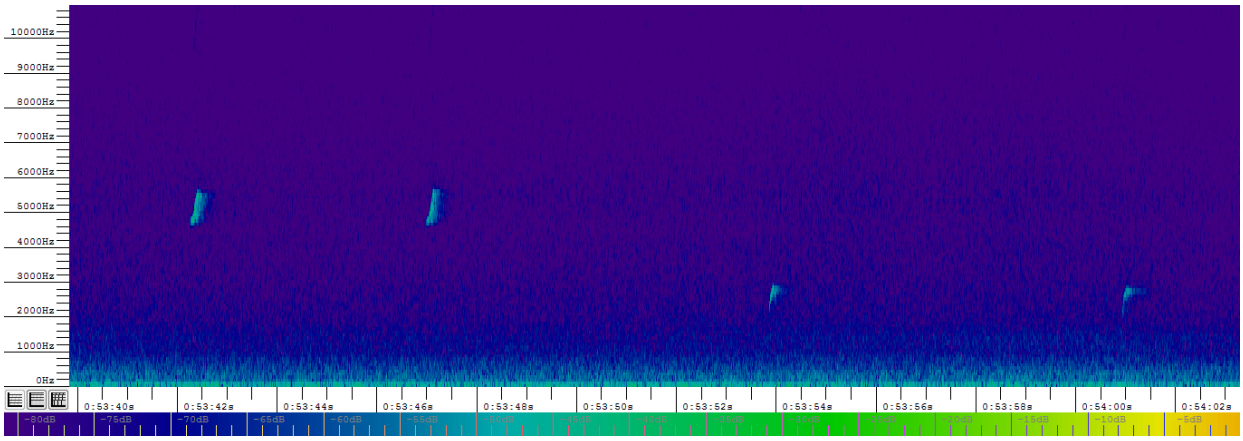

Figure 5. Sonograms of two “seep” calls followed by two contact calls.

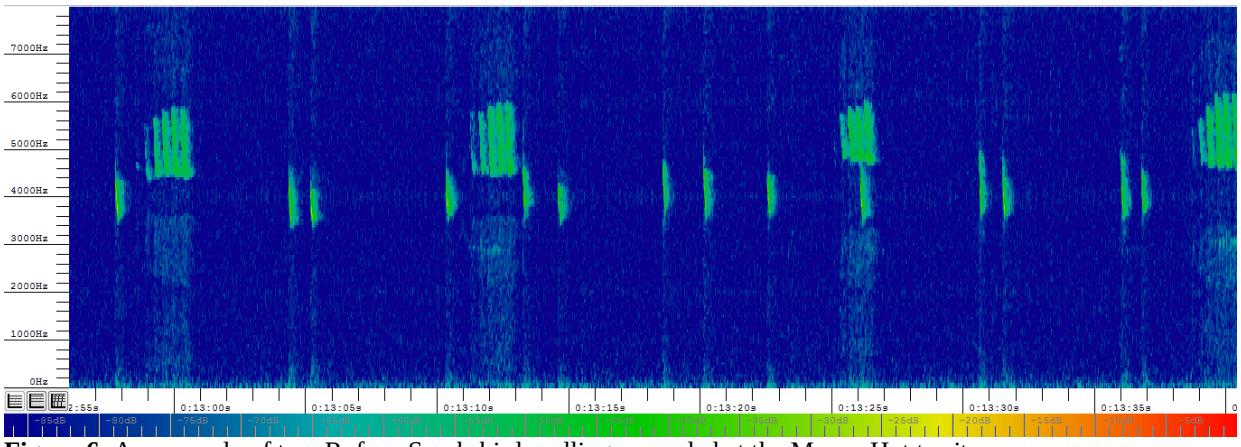

Figure 6. An example of two Rufous Scrub-birds calling, recorded at the Munro Hut territory.

53% of the phrases delivered in the period were multiple syllable chipping calls, with the balance being various single syllable phrases. The following morning, 193 phrases were delivered during 11 calling bouts (two of these extended before / after the selected time period). 48% of the phrases were multi-syllable ones, with 45% being single syllable phrases and the balance (7%) assigned to mimicry.

Table 2. Summary of the Munro Hut Rufous Scrub-bird calling patterns in two one-hour sessions

Calling Patterns	20 Sep 16:30-17:30	21 Sep 8:00-9:00
Number of bouts	12	11
Number of phrases delivered	245	193
% of multiple chip phrases	53%	48%
% time spent in calling bouts	79.6%	70.2%
Longest calling bout (sec)	1470	926
Shortest calling bout (sec)	27	28
Longest period silent (sec)	351	709

The longest bout in the afternoon session lasted for 24.5 minutes and involved 93 multi-syllable chip calls uttered at an average interval of 13 seconds. This bout was preceded by a 33 second bout of "seep" calls with only a short pause between the two. That is, there was around 25 minutes of near-continuous calling. Over the full hour, only two of the pauses between bouts exceeded 100 seconds, with the longest pause being 351 seconds. The scrub-bird was calling for almost 80% of the time.

The next morning, the longest bout lasted nearly 15.5 minutes. It was followed by 11.8 minutes of silence. There were two additional long duration calling sessions, 476 seconds and 527 seconds (~8 minutes, ~9 minutes) respectively, which involved a change from single to multiple syllable phrases part way through. In each case, the intervals between the two types of bout were <10 seconds. The scrub-bird called for around 70% of the one hour morning period.

In the shorter multiple syllable bouts, the number of syllables per phrase was predominantly 4 and a maximum of 5. In the more prolonged bouts the number of syllables increased during the bout, generally reaching a maximum of 7 syllables. The 24.5 minute bout on 20 September included a few 9-syllable phrases. Most bouts started with a succession of double syllable chip phrases before building up.

In the multiple syllable bouts, the typical interval between phrases was 13-23 seconds (range 9-45 seconds). In contrast, the single syllable calls were usually more closely spaced, with intervals typically of 4-14 seconds (range 1-33 seconds).

The intensive analysis of two one-hour periods at the Munro Hut territory in September 2011 is instructive in terms of what may be expected when a scrub-bird is actively calling. An obvious question is how often this is the case. The following chronological account addresses this point:

<u>September 20</u>
15:50: Song Meter™ installed
16:10: Bird resumed calling
16:30-17:30: See detailed analysis above
17:41: Last recorded (contact calls)

<u>September 21</u>
5:37: First recorded call (multiple chipping)
To 8:00: Calling very frequently
8:00-9:00: See detailed analysis above
All day: Calling very frequently
17:41: Last recorded (multiple chipping)

<u>September 22</u>
5:33: First recorded call (whistles)
To 6:20: Calling very frequently
6:20-6:40: Silent
6:52-8:22: Silent
8:36-9:36: Silent
9:37-10:50: Occasional calls heard
10:51-11:27: Calling very frequently
11:55: Song Meter™ removed

The Song Meter™ recorded throughout both nights; no Rufous Scrub-bird calls were detected. In the period 21-23 September, dawn was at 5:44am and sundown at 5:49pm. The scrub-bird began calling 5-10 minutes before dawn, and became silent 8 minutes before dusk.

It was not feasible to analyse in detail the calling pattern throughout the entire time, mainly because on several occasions the recordings were too faint for reliable analysis. At such times, presumably the bird was further away from the Song Meter™. Nevertheless, it was obvious that the calling patterns throughout daylight hours on 21 September were similar to those found in the detailed 1-hour analyses. Multi-syllable chipping calls were predominant, and a variety of single syllable phrases were also delivered. By extrapolation from the two 1-hour detailed analyses, where the calling rate was found to be 11-12 bouts/hour and 200-250 phrases/hour, the scrub-bird issued 2,500-3,000 calls in 130-150 calling bouts on 21 September. In effect, the day appeared to be one continuous calling session.

Table 3. Calling patterns of Munro Hut Rufous Scrub-bird in two one-hour sessions.

Calling Bouts				Phrases in the Calling Bout				Syllables per Phrase	
Start time	**Finish time**	**Duration (s)**	**Pause time before next bout (s)**	**Type**	**Number in bout**	**Average interval (s)**	**Range of intervals (s)**	**Average No.**	**Range**
16:30:00*	16:33:18	>198*	22	Multiple chips	>7*	30	11-45	4	4
16:33:40	16:36:32	172	351	Seep	19	9	2-13	1	1
16:42:23	16:43:43	80	4	Contact call	15	5	3-8	1	1
16:42:23	16:45:03	76	52	Whistle	11	7	5-12	1	1
16:44:31	16:47:57	122	21	Single chip	15	8	1-16	1	1
16:46:54	16:53:28	310	12	Multiple chips	22	13	9-39	4	2-7
16:52:16	16:54:07	27	38	Contact call	20	1.3	1-5	1	1
16:53:21	16:57:37	172	86	Multiple chips	8	18	15-27	4	4-5
16:57:39	16:59:36	33	12	Seep	2	33	33	1	1
16:58:24	17:24:18	1470	118	Multiple chips	93	13	7-33	5.6	2-9
17:24:52	17:27:48	92	18	Contact call	20	5	3-9	1	1
17:26:42	17:30:00*	>118*	N/A	Thrip	>13*	9.5	6-14	1.3	1-2
Next morning									
8:00:01*	8:05:03	>302*	-	Single chip	>35*	9	4-16	1	1
8:05:03	8:07:57	174	20	1-3 chips	14	12	5-19	2.4	1-3
8:08:16	8:09:38	82	21	Whistle	14	7	4-10	1	1
8:09:59	8:10:27	28	22	Mimicry	3	16	12-22	2.6	2-3
8:10:49	8:14:22	213	195	Multiple chips	10	23	14-41	4.2	4-5
8:17:37	8:19:50	133	-	Whistle	10	13	9-17	1.6	1-2
8:19:50	8:26:24	394	31	Multiple chips	24	17	9-28	3.1	1-4
8:26:55	8:28:21	86	61	Whistle	24	4	1-13	1	1
8:29:22	8:32:16	174	14	Mimicry	11	17	11-25	1	1
8:32:30	8:47:56	926	709	Multiple chips	45	21	14-42	5.6	3-7
8:59:45	9:00:02*	>17*	N/A	1-2 chips	>4*	9	8-9	1.3	1-2

**Bout incomplete as either in progress or continuing when analysis period started or finished*

The contrast in calling pattern on 22 September is quite striking. The scrub-bird began calling shortly before dawn, and called often during the following 47 minutes, much like the previous day. However, in the subsequent 3.5 hours, only about 30 minutes of calling bouts were detected. Later, from around 10:50am, the calling rate increased.

It is possible that on 22 September the scrub-bird was recorded less frequently because it may sometimes have been out of range of the microphones, and not detected. For example, at 9:36am, very faint chipping calls could be discerned which over the next 15 minutes became progressively louder, followed by 6 minutes in which loud calls were recorded, to 9:56am. After then, the bird became silent, except for occasional faint (and presumably, distant) calls until 10:51am, when a new pattern of frequent calling began.

At this stage, there seems no ready alternative explanation for the different calling behaviour on the two days.

Calling patterns of the Munro Hut Rufous Scrub-bird in other months

February 2011

The Song Meter™ was in position for ~50 hours, from 12:45pm on 10 February. It recorded from 5:30am to 8:30pm daily. The weather conditions are believed to have been favourable for at least the majority of the time that the Song Meter™ was in place.

In this first attempt at long-term monitoring, the unit was not placed as close to the calling node of the territory and this made detailed analysis of the bird's behaviour difficult. It began calling just after 6:30am both mornings, shortly after dawn. The first morning involved a 30-minute calling session, with some multi-syllable phrases. Dawn calling on the second morning was for just 15 minutes. Over all three days, the scrub-bird only called intermittently. Most of the bouts involved single syllable phrases, delivered in calling sessions of <10 minutes. Often there was an interval of an hour or so before the next calling session began. Multi-syllable phrases were uncommon, and usually involved a maximum of 4 syllables. Leading up to dusk on the first evening, the bird called for 10 minutes using 7-syllable phrases. However, the following evening it only uttered sporadic calls before dusk, with most of these being single syllable phrases.

May 2012

The Song Meter™ was in place for ~148 hours, from 9:30am on 16 May. It recorded from 6:30am to 7:00pm daily. The weather conditions during the recording session were not always favourable, as evidenced by the frequently recorded presence of background noise due to wind, in particular in the final 2 days.

The scrub-bird commenced a 20-30 minute calling session at about 6:30am each day. During each day, there were several calling sessions, typically lasting for 15-30 minutes. At other times, the bird was silent or issued single phrases occasionally. In general, each calling session involved several bouts in between which the bird was silent for a few minutes.

Although many multiple syllable phrases were delivered during each day, it was uncommon for them to be of >3 syllables. Single syllable phrases predominated. Also there was a higher proportion of calls assigned to mimicry. However, in the late afternoon leading into dusk, the scrub-bird had longer calling sessions. These lasted for 1-2 hours and involved many multi-syllable phrases, up to a maximum of 11 syllables in a calling session which commenced at 3:15 pm on 18 May. A 1-hour calling session from 8:20am on 19 May also involved many multi-syllable phrases, including some of 10 syllables.

Detectability of Rufous Scrub-birds by intrusive and non-intrusive methods

Transects walked at 1 km/h

Under ideal conditions, an experienced surveyor can hear a calling scrub-bird from >150m away (Ferrier 1984). For transects conducted at 1km/h (Newman & Stuart 2011) on walking tracks through potential scrub-bird territories, the surveyor will spend 12-20 minutes within earshot of a scrub-bird if it calls (the time depends on how far in from the track the bird happens to be). The probability that a diligent surveyor will detect a scrub-bird depends on whether the bird calls during the time that the surveyor passes through the territory. On 21 September, and in the afternoon of 20 September, the probability that the scrub-bird would have been detected is 100%, as the intervals between calling sessions were <10 minutes. The following day, the bird only called for a total of 26 minutes between 6:20 am and 9:36 am and the probability of its being detected during that period is low (estimated at <15%). Its

detectability then increased since it began calling more often.

In February 2011, the Munro Hut scrub-bird called infrequently, in sessions lasting <10 minutes and with long intervals between sessions. The probability that it would have been detected is low. In May 2012, the scrub-bird was readily detectable for periods around dawn and dusk. For the remainder of the day, it called for periods of 15-30 minutes with silence or occasional single syllables in the intervening times. The probability of it having been detected in May, in a single transect through the territory at 1km/h, was estimated to be in the range 25-50%.

For a surveyor only able to reliably detect the multi-syllable chipping call, the scrub-bird's detectability is further decreased since many of the calling bouts, especially in February and May, involved single syllable calls or mimicry.

Transects at 2.5 km/h by an experienced surveyor

At 2.5km/h there would be a period of 4-6 minutes, depending how far from the track the bird was, in which a surveyor would hear the bird if it was calling. Applying this faster transect pace to the Munro Hut scrub-bird would appreciably lower its detectability, particularly for an observer relying on the chipping call being used. However, an experienced surveyor who is able to recognise other calls of the Rufous Scrub-bird has greater opportunities to detect the bird.

Ferrier (1984) developed an algorithm to predict the detectability of Rufous Scrub-birds in transects walked a single time at 2.5km/h by an experienced surveyor. The results from the present study fit moderately well with Ferrier's predictions. **Figure 7** superimposes our estimates of the detectability of the Munro Hut scrub-bird in transect surveys walked at 2.5 km/h onto plots of Ferrier's algorithm for Gloucester Tops scrub-birds under three sets of conditions:

- Most favourable conditions (humidity >85%, no wind/mist)
- Poor conditions (humidity <60%, moderate wind, some mist)
- Very adverse conditions (humidity <60%, high wind, dense mist)

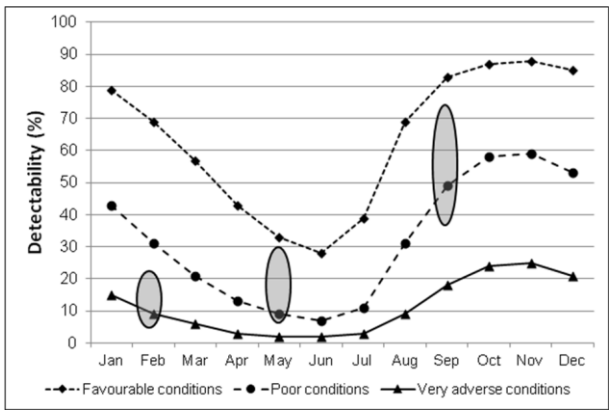

Figure 7. Predicted detectability of the Munro Hut Rufous Scrub-bird in February, May and September, superimposed on the predictions by Ferrier (1984) for Gloucester Tops scrub-birds.

In **Figure 7**, ranges are used for predicting the detectability of the Munro Hut Rufous Scrub-bird in February, May and September. The ranges reflect that sometimes the scrub-bird called more frequently than at other times. More precise predictions of the detectability are beyond the scope of this paper. The superficial agreement between our analysis and Ferrier's algorithm is good for the May and September periods. However, in February 2011, when the conditions are understood to have been generally favourable, we found the detectability of the Munro Hut bird to be much lower than predicted from Ferrier's algorithm. It is important to note that the algorithm was derived for a population of Rufous Scrub-birds and the behaviour of individual birds is probably less readily predicted.

A stationary surveyor

It is useful to consider how long a surveyor need remain at a suspected Rufous Scrub-bird territory in order to confirm that it is occupied. In September, the longest interval between calling sessions was 90 minutes, in the morning of 22 September. Most of the calling sessions had far shorter intervals. In February and May, the scrub-bird had calling sessions at intervals usually of less than 1 hour, although often these were only a few minutes duration and did not involve multi-syllable chipping calls. The longest interval between calling sessions was 102 minutes (on 10 February).

If a surveyor had waited for 2 hours at the Munro Hut scrub-bird territory in February, May or September, they would have detected the bird provided that they were familiar with the full repertoire of Rufous Scrub-bird calls and that they

remained diligent throughout their wait (and that weather conditions did not become adverse).

The alternative to a fixed surveyor is to use a Song Meter™. This has marked advantages if the unit is deployed overnight because our studies indicate periods of increased calling activity near dawn and dusk, when it is difficult logistically to have a surveyor in place given Rufous Scrub-birds live in remote areas. Indeed if a Song Meter™ deployed for 24 hours failed to detect a calling Rufous Scrub-bird in the breeding season it could be confidently concluded that a territory was unoccupied.

Automated analysis of recordings

Using the Song Scope™ software, an electronic "recogniser" for the multi-syllable chipping call of the Rufous Scrub-bird has been developed, based on a set of calls made by the Munro Hut scrub-bird. Because of the varied quality of recordings, the "recogniser" is far from ideal as yet. Of the 222 multi-syllable calls delivered during the two 1-hour detailed analyses, only 23.6% were detected by the "recogniser". Therefore, it is not able to be used for detailed analysis of recordings. However, as Rufous Scrub-bird calling bouts can involve 20 or more phrases, the probability of detecting at least one multi-syllable chipping call during a bout is very high. For example, for a bout of 20 calls, the probability of detecting the bout is >99.5%.

The electronic "recogniser" has successfully identified calls by scrub-birds in recordings made at the other sites listed in **Table 1**. Thus, it can be used to assist rapid screening of whether a scrub-bird is present at a particular site, or to check if it made any calls within some period of interest.

CONCLUSIONS

The Song Meter™ has been shown to be an effective and non-intrusive means of studying Rufous Scrub-birds. Their calling patterns have been shown to vary during the year. This has implications for the monitoring program, as sometimes there will be only a low probability of successfully detecting a scrub-bird at its territory. It will be important to further improve the understandings about how the scrub-bird's calling patterns vary during the year.

Some progress has been made in developing a software-based means of rapid and automated scanning a Song Meter™ recording for Rufous Scrub-bird multi-syllable calls. Although it fails to detect many individual phrases, the probability of detecting a bout of calls is high.

Future directions

One aspect of the future work will be to record the Munro Hut scrub-bird in many other months of the year, to improve understandings of how the calling patterns vary. We also aim to extend this seasonal study to some other Rufous Scrub-bird territories in the Gloucester Tops, to see if the patterns are similar for those other birds. Anecdotal evidence suggests that the Munro Hut bird calls more frequently than other scrub-birds in the Gloucester Tops area.

Further development of the software-based "recogniser" will be targeted. This will improve its usefulness as a tool that assists the ongoing studies. Extension to "recognisers" for other Rufous Scrub-bird calls, for example "seeps" and "whistles", will also be addressed. This software development will make it easier to screen for scrub-birds at suspected or previously inhabited territories.

Of longer-term interest will be to investigate whether individual scrub-birds can be identified from their sonogram signals. If so, that potentially will allow non-intrusive studies of the longevity of individual birds. The technique has been used successfully for some species, for example Rufous Bristlebirds *Dasyornis broadbenti* (Rogers & Paton 2005). However, Noisy Scrub-birds *A. clamorus* could not be identified individually (Portelli 2004) and Portelli was pessimistic about the prospects with *A. rufescens*.

Finally, it is clear that the non-intrusive nature of the Song Meter™ has a potential role in the monitoring of other cryptic territorial species, for example bitterns, crakes, owls.

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