Rufous Scrub-bird *Atrichornis rufescens* monitoring at the extremities of the species' range in New South Wales (2010–2012)

Mike Newman[1]*, *Alan Stuart*[2] *and Faye Hill*[3]

[1]72 Axiom Way, Acton Park TAS 7170, Australia. Email: omgnewman@bigpond.com
[2]81 Queens Road, New Lambton NSW 2305, Australia. Email: almarosa@bigpond.com
[3]207 Blakeneys Road, Stokers Siding NSW 2484, Australia. Email: fayelillian@hotmail.com
*Corresponding author

Summary. The status of the Rufous Scrub-bird *Atrichornis rufescens* was monitored between 2010 and 2012 using volunteers at Gloucester Tops and the Border Ranges National Park, high-altitude locations at the extremity of the species' range in New South Wales. Transects were walked to determine the densities of calling territorial males, allowing comparison with similar studies 30 years earlier. Both locations have been nominated as Important Bird Areas, based on their importance to the remnant populations of the Scrub-bird. Gloucester Tops is the southern extremity of the range of the subspecies *A. r. ferrieri*, where there was evidence of a slight increase in abundance and clustering of territories. This is consistent with the possibility of population retreat to high-altitude remnant montane habitat. In contrast, in the Border Ranges, territory densities of the subspecies *A. r. rufescens* were slightly lower than at Gloucester Tops, and may have declined slightly compared with the earlier study. Both areas are in passively managed National Parks, but Rufous Scrub-birds are found in different vegetation types: eucalypt forest at Gloucester Tops and rainforest in the Border Ranges. At both these locations, there was a 30–35% decrease in the detection of Scrub-bird territories in 2012 compared with the previous 2 years. This is attributed to dry conditions during August–November, entering and during the Scrub-bird's breeding season. Ongoing monitoring is essential to determine whether this decrease is temporary, because the birds were calling less, or permanent.

Introduction

The Rufous Scrub-bird *Atrichornis rufescens* has a restricted range and is classified as Vulnerable under both the New South Wales (NSW) *Threatened Species Conservation Act 1995* and the IUCN Red List classification. This species triggered the nomination of five Important Bird Areas (IBAs), four in northern NSW and one on the NSW–Queensland border. The locations of the remnant Scrub-bird populations are shown in Figure 1. Monitoring the status of trigger species is a requirement of the IBA process (Dutson *et al.* 2009). This paper describes monitoring of Scrub-birds between 2010 and 2012 at Gloucester Tops and in the Border Ranges National Park, which are part of the Barrington/Gloucester Tops and Scenic Rim IBAs, respectively. The Rufous Scrub-bird was a 'value' for the listing of the Gondwana Rainforests of Australia World Heritage Area, which includes the two IBAs central to this study.

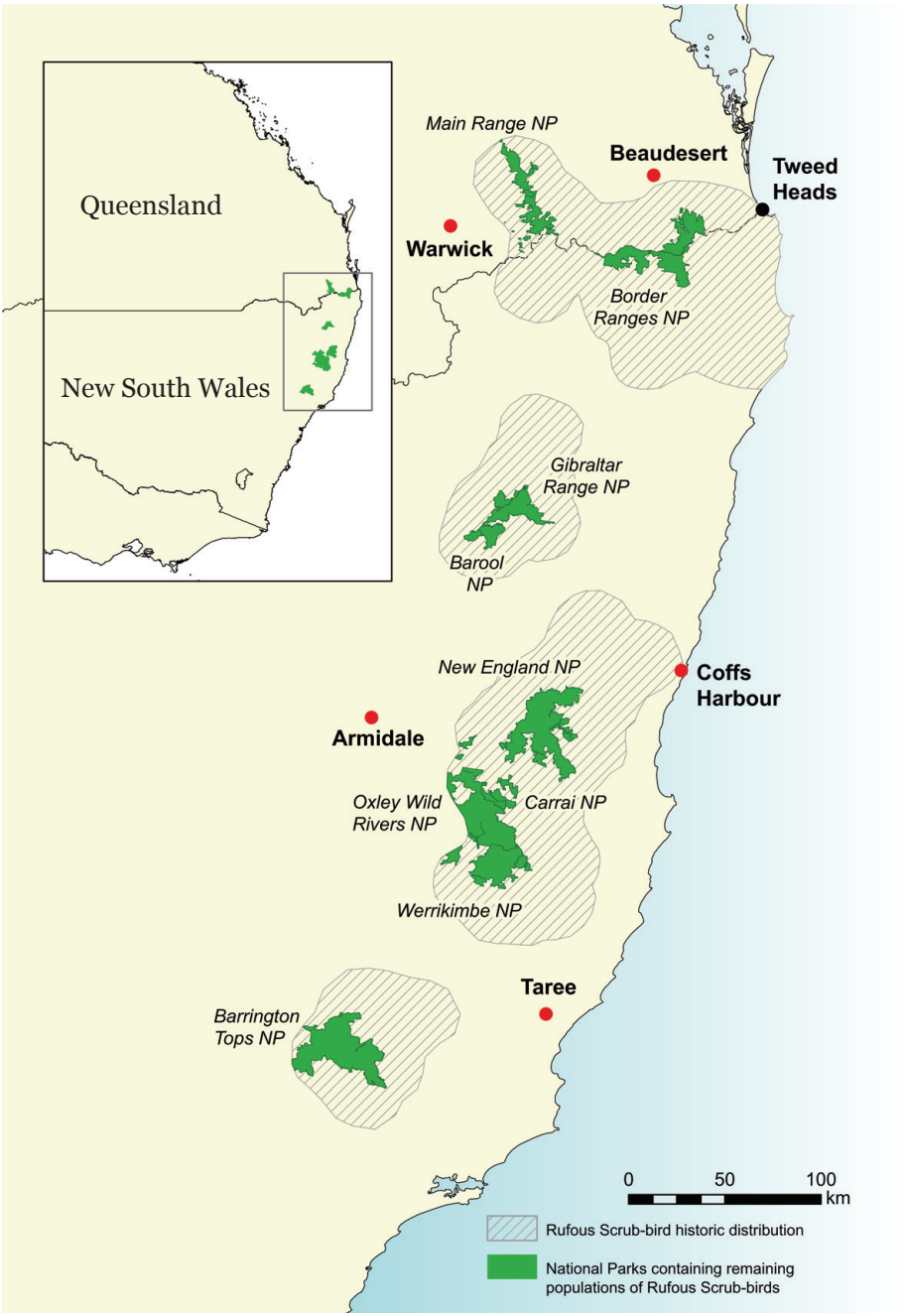

Figure 1. Current and historic distribution of Rufous Scrub-birds. NP = National Park. Map details were supplied by Shane Ruming, New South Wales Office of Environment and Heritage.

Ferrier (1984, 1985) investigated the status of the Rufous Scrub-bird at all areas currently known to support the species. These remnant populations are all at high altitude, typically >800 m above sea-level (asl). The species is now considered to be either extinct or exceedingly rare in its former lowland range (Ferrier 1985). Subsequent to Ferrier's definitive studies, two subspecies of the Rufous Scrub-bird have been recognised (Higgins *et al.* 2001). The northern subspecies *A. r. rufescens* is localised in extreme south-eastern Queensland and far north-eastern NSW, from the Mistake Range, Qld, to the Gibraltar Range, NSW. This region includes the Scenic Rim IBA, which incorporates the Border Ranges and Main Range National Parks. The southern subspecies *A. r. ferrieri* occurs in central north-eastern NSW, from the Dorrigo Plateau south to Barrington Tops. This region includes the Barrington/Gloucester Tops IBA. Ferrier's studies were most comprehensive for the Border Ranges National Park (formerly Wiangarie State Forest) and Gloucester Tops populations, which occur at the northern and southern extremities of the Rufous Scrub-bird's distribution, respectively. His two study areas also reflect extremes in habitat. The northern subspecies inhabits mostly subtropical rainforest at altitudes ranging from 700 to 1100 m asl, whereas the southern subspecies is found mainly in eucalypt forest at altitudes ranging from 900 to 1300 m asl. The monitoring described in this paper occurred in many of the same areas as Ferrier (1984, 1985) used, allowing comparison with his work 30 years earlier.

Rufous Scrub-birds live in dense moist understorey on the edges and within rainforest or in more open eucalypt forest. Within this habitat they are remarkably difficult to see, being dark-coloured and secretive as they move through the undergrowth like rodents. From a monitoring perspective, it is fortunate that the male advertises his territory with loud calls uttered frequently, particularly during the breeding season (Ferrier 1984; Newman & Stuart 2011; Stuart *et al.* 2012). The detection of calling territorial males is the basis of the studies described in this paper. As the remnant Scrub-bird populations are found in remote areas, often involving inaccessible terrain, it is also fortunate, from a monitoring perspective, that Scrub-birds are known to occur in areas adjacent to tracks and creeks. All the monitoring here was conducted from existing vehicular and walking tracks.

Ferrier's (1984) approach involved walking transects and finding all Rufous Scrub-bird territories occupied by calling males within 150 m either side of the track. He found that calling birds were most easily detected between September and December under conditions of high humidity, low wind and low mist. Time of day did not appear to be a critical parameter. Ferrier estimated 24 males to be advertising permanent territories at Wiangarie (Border Ranges) and 18 at Gloucester Tops during the 1981 breeding season. The implied densities were 4.4 territories km^{-2} and 3.3 territories km^{-2}, respectively. However, under favourable conditions, Ferrier suggested that densities even as high as 6 territories km^{-2} were possible (Ferrier 1984).

Ferrier (1985) found that critical factors determining whether habitat was suitable for Rufous Scrub-birds appeared to be identical across the species' range despite broad differences in forest types. Typically, major requirements were extremely dense cover 2–50 cm above the ground, moderately dense cover

50–100 cm above the ground, a moist microclimate at ground-level, and abundant leaf-litter. Suitable habitat at Wiangarie (Border Ranges) occurred as small isolated patches beneath gaps in the rainforest canopy. In contrast, at Gloucester Tops, suitable habitat generally occurred as long strips within eucalypt forest fringing the edge of rainforest.

More recent monitoring (1999 and 2004) was commissioned by the NSW National Parks and Wildlife Service. This study, co-ordinated by Birds Australia (now BirdLife Australia), mainly using volunteers, again involved detecting calling males during the breeding season (Ekert 2002; Ecological Australia 2009). In these studies, a number of fixed points 400 m apart were established and monitored annually using a standard protocol to determine the presence or absence of calling Rufous Scrub-birds. The intent was to determine temporal trends of an index of annual abundance. No attempt was made to distinguish between males advertising permanent and temporary territories. The Birds Australia study sampled a larger area of potential habitat, including transects monitored in this study, as well as locations at lower altitude.

During the 2010/2011 breeding season, Hunter Bird Observers Club (HBOC) volunteers conducted a successful pilot study at Gloucester Tops as a basis for future ongoing long-term monitoring of Rufous Scrub-birds (Newman & Stuart 2011). Volunteers from the Tweed Bird Observers conducted a parallel study in the Border Ranges National Park. In both studies, we elected to use transect surveys for calling male Scrub-birds, similar to those conducted by Ferrier, which provide an absolute measure of territory densities, as opposed to a relative index of abundance. Our choice addressed concerns raised over previous approaches (Ecological Australia 2009), and allowed a comparison with Ferrier's baseline data. The choice also fitted well with our intent to conduct an intensive set of BirdLife Australia Atlas surveys for all bird species, with added focus on other species listed to support the IBA nomination of the two areas. In both Ferrier's and our investigations, the results were broken down into transect segments involving 1 km linear length of track (i.e. taking into account curves and undulations). The same monitoring approach was implemented contemporaneously by the NSW Office of Environment and Heritage (Parks and Wildlife) at Killiekrankie (Mick Andren and Peter Higgins pers. comm.) and in the New England and Werrikimbie National Parks. Both these areas are known to support populations of Scrub-birds (Ferrier 1984), and have been assigned IBA status. Williams's (2012) study involved repeating Ferrier's original survey transects. The results of all these studies were not available to the authors when this paper was prepared.

Our ongoing monitoring uses continuity of occupation of breeding-season territories as a key indicator. Knowing how frequently and when territorial male Rufous Scrub-birds call is central to determining how much survey effort is required before it can be assumed that a territory is not being advertised and may have been abandoned. Although Ferrier's (1984) detection factors, based on the average behaviour of a population of Scrub-birds during surveys, are valuable in addressing this point, we also initiated a new approach using a Song Meter deployed in individual territories at Gloucester Tops to provide additional insights (Stuart *et al.* 2012).

Methods

Surveys were carried out by volunteers at Gloucester Tops in the Barrington Tops National Park (32°05′S, 151°36′E) and in the Border Ranges National Park (28°23′S, 153°05′E) each breeding season (mainly September–November) between 2010 and 2012.

Transects were established along roads and walking tracks in both the study areas: 20 km at Gloucester Tops (Figure 2) and 12 km at Border Ranges (Figure 3). One-kilometre segments were measured either by odometer readings where car access was possible or by measurement on Google maps to determine end-point map co-ordinates. These points were found using GPS units set to WGS84 co-ordinate system. All transect segments were marked at their extremities with coloured tape. At Gloucester Tops, the selected transects corresponded with ~70% of the area surveyed by Ferrier (1984) and also with a number of the fixed survey sites used in the previous Birds Australia study (Ekert 2002; Ecological Australia 2009). Tweed Bird Observers transects were a subset of Ekert's (Transect 6 Brindle Creek, Transect 8 Sheepstation Creek, and Transect 9 Booyong Walk) (Ekert 2002; Ecological Australia 2009), where the Rufous Scrub-bird records had been found to be most numerous. This choice was consistent with the recommendations of a review of that work (Ecological Australia 2009) and did not overlap Ferrier's transects.

Detection of territories

Reliable detection of calling Rufous Scrub-birds is central to locating their territories. Previous studies have indicated that during the breeding season the probability of hearing males having territories within 150 m of transects usually exceeds 40% and can be as high as 80% for an experienced surveyor under favourable conditions, namely high humidity and absence of mist combined with low wind (Ferrier 1984).

The main call of the Rufous Scrub-bird has been described as a 'chipping' call (Ferrier 1984). It consists of repeated phrases, each involving several syllables. Once heard, this call is easily distinguished from other species by experienced surveyors. Our Song Meter studies indicated that, when undisturbed, 50% of the Scrub-bird's repertoire in September involved this call (Stuart *et al.* 2012). A high reliability was placed on records involving Scrub-birds using the chipping call. Males often call persistently over long periods of the day. Experienced surveyors used the chipping call, other known Scrub-bird calls and mimicry to detect Scrub-birds, but confirmation of a territory required that the chipping call was heard on at least one survey.

Data collection and management

A 3-day camp at the Gloucester Tops study area in September 2010, involving nine volunteers including two from the Tweed Bird Observers, was used to trial the survey methods. On the first day, the volunteers were trained to recognise calling Rufous Scrub-birds. After playing tapes of Scrub-bird calls (northern subspecies), participants were taken to a known Scrub-bird territory, where the resident male called persistently, mostly using his chipping call (Munro Hut territory; see Stuart *et al.* 2012). They then practised identifying the location of the calling bird, which included estimating the perpendicular distance from the track.

Five teams were formed, each involving at least one person previously experienced in locating Rufous Scrub-birds and familiar with the survey techniques. Each team was asked to survey between three and five transect segments, each 1 km in length. The following information was recorded:

1. GPS co-ordinates, side and distance from track of any Scrub-bird, either heard or seen;

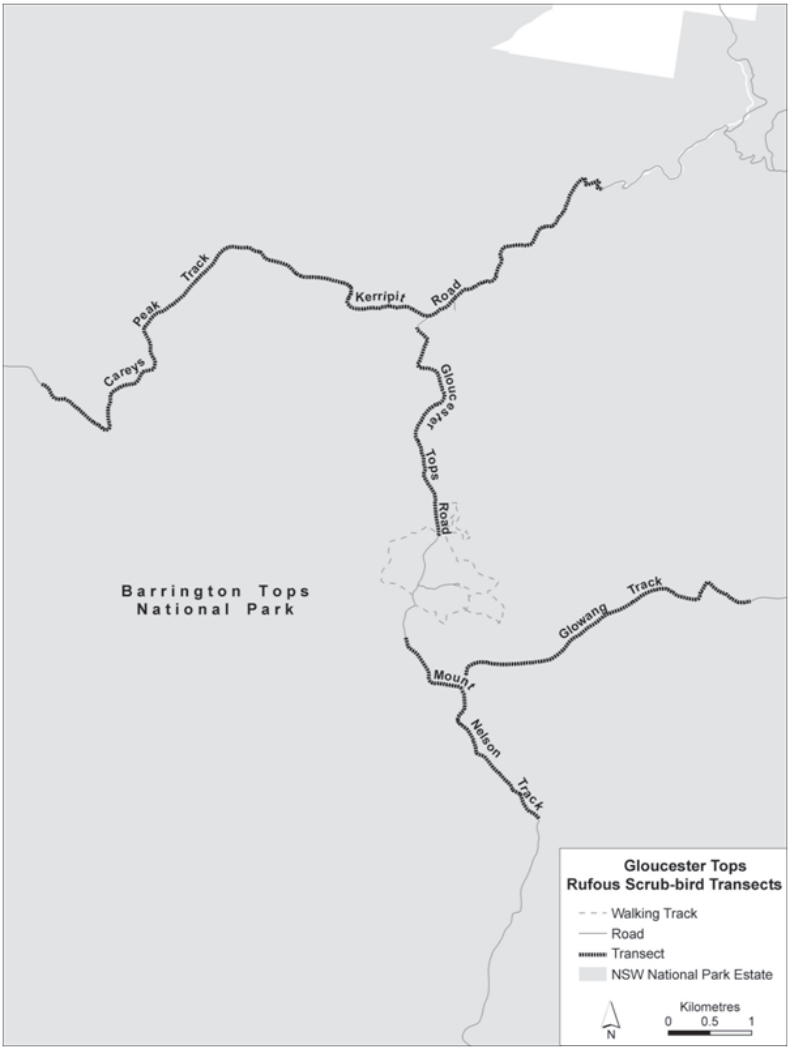

Figure 2. Survey transects at Gloucester Tops, NSW.

2. Types (e.g. chipping, mimicry etc.) and duration of calls heard;
3. Information relating to the detectability of Scrub-birds (e.g. humidity, wind strength, cloud cover and time of day);
4. An indication of the habitat type (e.g. eucalypt or rainforest canopy and the density of ground and mid-storey vegetation); and
5. All other bird species detected in each transect segment.

Surveys usually commenced at ~0800 h and took 4–6 h to complete. Typically, 1 h was spent in each 1-km segment; the actual time varied depending on whether any Scrub-birds

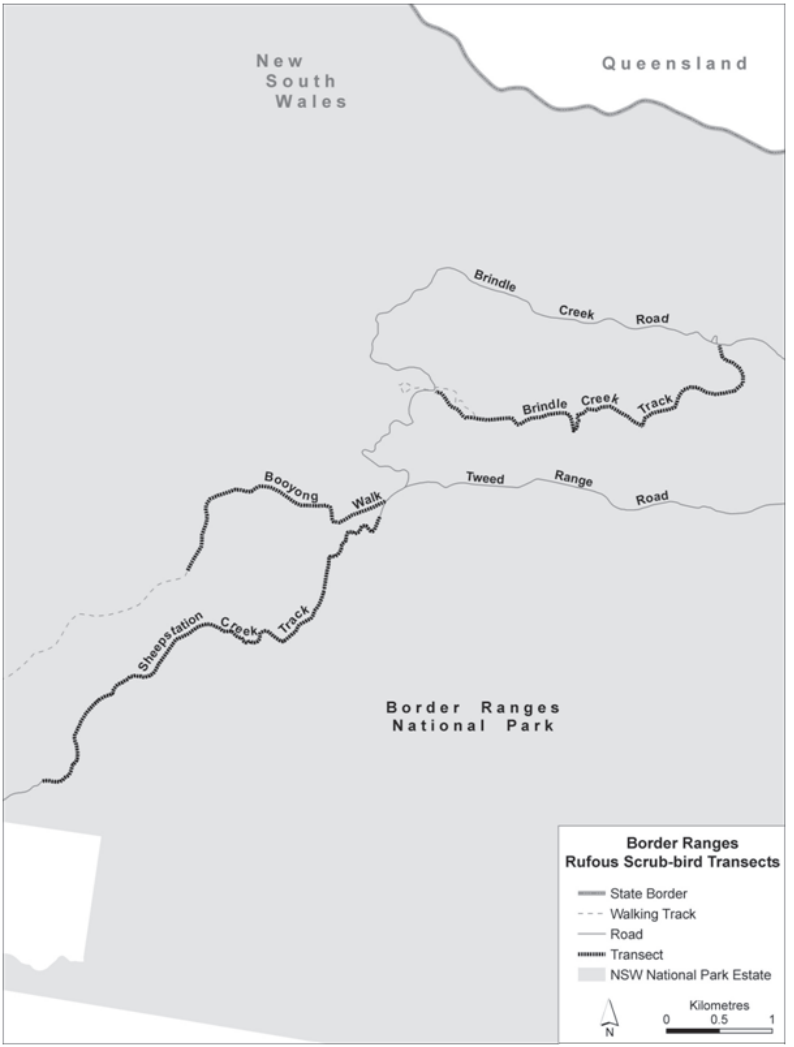

Figure 3. Survey transects at Border Ranges, NSW.

were located. When Scrub-birds were found, ≤10 minutes additional time was spent at the location to determine the types of calls used and the persistence of calling. In instances when apparent clusters of calling birds occurred, it was necessary to spend extra time, ideally proving that more than one bird was calling simultaneously. It was deemed more important to be certain that Scrub-birds were correctly identified and assigned as precisely as possible to accurately measured territories than to standardise the time spent surveying each transect segment. When observers had to return along a walking track through a set of transect segments, as occurred for ~50% of transects at Gloucester Tops, all Scrub-bird records were noted on both the outward and inward walk. This provided additional information on the size of territories and the persistence with which Scrub-birds call. Observers were discouraged from attempting to attract Scrub-birds by call-playback or

'pishing' and from leaving the track to seek out calling birds. Surveyors recorded all species within each 1-km transect. The resulting data were submitted to the BirdLife Australia Atlas (Birdata) as 500-m-radius area surveys.

This approach was successful and was subsequently used at two camps annually in the Border Ranges National Park. At Gloucester Tops, there were two camps in both 2010 and 2011, but only one in 2012, which was supplemented by day visits. When volunteers were available, additional areas involving ~10 km of tracks were surveyed opportunistically at Gloucester Tops.

Weather conditions in both study areas were unpredictable. At Gloucester Tops, observers had to wade across the Gloucester River to reach several survey transects. This was not always possible, so some transects received less survey effort than others. In the Border Ranges, survey effort was almost exclusively limited to four sets of surveys, two on successive days, at both of the camps conducted during each of the 3 years. Other records primarily involved birds detected when marking transects and driving along the surveyed section of Tweed Range Road, between Forest Tops Camping Ground and the western entrance of the park in the afternoons. No Song Meter studies were conducted in the Border Ranges, and observer training in call identification there was limited to listening to recorded calls of the northern subspecies. Continuity of involvement of core participants was good, and in 2011 and 2012 all records involved observers previously experienced in call recognition.

Interpretation

Male Rufous Scrub-birds occupy permanent territories and do 80% of their calling from within ~1 hectare (Ferrier 1985), but usually call from a restricted zone ~50 m in diameter (Ferrier 1984). Immature males hold and advertise temporary breeding-season territories. Ferrier (1984) assigned permanent territory status only to Scrub-birds for which there were records spanning the duration of the breeding season. Female Scrub-birds seldom call, and their call, described as a soft 'tick' (Ferrier 1984), causes little confusion.

Most of the surveys in the 2010 pilot study were carried out by teams camping in the area; the timing of camps was separated by ~1 month. Rufous Scrub-birds recorded at the same locations during both sets of surveys were accorded territorial status, even though this was a less rigorous criterion than Ferrier's for eliminating immature males holding temporary territories. At the end of the 2010 breeding season, locations where Scrub-birds had been heard were assigned either confirmed (where there were at least two records separated by 1 month) or tentative (where there was insufficient evidence to conclude continuous occupancy—e.g. a single record or multiple records <1 month apart) status. If Scrub-birds were subsequently heard at tentative sites in 2011 or 2012, the sites were deemed as confirmed. Unconfirmed sites were dismissed as either those of non-breeding males seeking to establish territories, or misidentification.

When Rufous Scrub-bird territories are separated by >0.5 km, confirmation is straightforward. However, when records are clustered, interpretation is more difficult because of the need to differentiate between males advertising adjacent territories and one male calling from an elongated territory with more than one calling node (Ferrier 1984). There is also the possibility of a male and female duetting, although this is rare (Ferrier 1984). In instances of ambiguity, surveyors were encouraged to spend additional time in the vicinity of clustered records, and ideally to ascertain whether more than one bird was calling simultaneously. In reviewing results, a conservative approach was taken: for instance, observations spread along an extended segment of track were attributed to a single elongated territory with multiple calling nodes as opposed to several clustered territories unless there was strong evidence to the contrary (such as two birds calling simultaneously); this rationalisation was necessary at Gloucester Tops but not Border Ranges.

In subsequent years, the primary challenge for survey teams was to determine whether territories occupied the previous season were still occupied. Surveyors were supplied with details of the location of territories and encouraged to spend additional time (at Gloucester Tops, but not in Border Ranges) if necessary to determine occupancy. However, transects were still walked in a similar manner to previous years to seek new territories.

Inevitably, some transects and Scrub-bird territories received more survey effort than others, particularly the Munro Hut territory on the Careys Peak Track at Gloucester Tops. Surveys conducted along this Track require the observers to return by the same route and the territory was passed twice, with an interval of ~5 h if all five transects were walked. Additional visits to this territory were made to train new volunteers in Scrub-bird call recognition, to place and retrieve a Song Meter (Stuart *et al.* 2012), and some casual visits to the territory; all these records were used in the analysis. At the other extreme were the remote territories at the extremities of the Mt Nelson, Glowang and Careys Peak Tracks, which received less effort because of access and distance difficulties.

Some Rufous Scrub-bird territories are easily identified and confirmed because they are close to tracks (e.g. primary calling node within 50 m of a transect). Others may be near the limit of detection for the species (150 m: see Ferrier 1984). The extent to which birds will be detected will also vary with survey conditions (Ferrier 1984) and with the hearing ability of individual volunteers. Unconfirmed records may be either temporary territories advertised by immature birds or permanent territories located at the detection limit (150 m) for calling Scrub-birds.

Results

At the end of each breeding season, the results were reviewed to take into account the additional confirmational evidence provided by that year's observations. Single records were dismissed as involving either temporary territories or misidentification. The following analysis is limited to territories considered to be permanently occupied by calling males throughout at least one breeding season.

Gloucester Tops

Following rationalisation, 33 territories were identified during 2010–2012 along 20 km of transects (Table 1); annual totals were 31 (2010), 31 (2011) and 20 (2012). Of these, 19 territories were held for all three breeding seasons. A further nine were occupied in the 2010 and 2011 breeding seasons, but there was no calling at these sites in 2012. The other five territories involve two found only in 2010, two found only in 2011, and one occupied in 2011 and 2012. No new territories were found in 2012.

Twenty-nine of the 31 territories identified in 2010 (94%) continued to be occupied in 2011 and satisfied Ferrier's criterion that a permanent territory should be demonstrated to be occupied throughout a complete breeding season (Ferrier 1984). However, only 20 of the 31 territories found in 2011 (65%) were occupied in 2012.

The strength of evidence for the identification of territories is reflected by the number of days on which Rufous Scrub-birds were heard calling at a territory (Figure 4). The variation in the number of days that territory occupation was confirmed in part reflects differences in survey effort, as discussed previously.

Table 1. Rufous Scrub-bird territories found during the breeding season at Gloucester Tops, NSW, in 2010–2012.

Track name	*Distance surveyed (km)*	*No. of territories*			*No. constantly occupied*	*Total territories found*
		2010	*2011*	*2012*	*2010–2012*	
Glowang	3	7	8	6	5	8
Mt Nelson	3	3	4	2	2	4
Gloucester Tops Road	3	4	3	1	1	4
Gloucester Falls	1	2	2	2	2	2
Careys Peak	5	9	8	5	5	9
Kerripit Road	5	6	6	4	4	6
Total	**20**	**31**	**31**	**20**	**19**	**33**

Figure 4a understates the evidence of territory occupation, as in many cases at Gloucester Tops occupancy was confirmed more than once on the same day. After the first year of the survey, and based on the assumption that male Scrub-birds may live ~10 years and occupy the same territory (Ferrier 1984), the primary objective was to establish continuity of occupation of territories between years. The mean number of days that a territory was confirmed to be occupied was 5.5. Only four of the 29 territories occupied in at least two consecutive years (14%) were based on single records in two different years.

During the 3 years, 2010–2012, Scrub-bird territories were found in 19 of the 20 transects surveyed regularly. The only transect with no territories was predominantly Antarctic Beech *Nothofagus moorei* forest on the second kilometre of the Careys Peak Track. The highest densities were 4 territories km^{-1} during 2011 in one transect on the Careys Peak Track and 3 territories km^{-1} in two transects on the Glowang Track and one on Careys Peak Track. In only one transect was the density sustained at 3 territories km^{-1} every year.

In 2011, and to a lesser extent in 2012, attempts were made to locate additional Scrub-bird territories outside the 20 km of tracks surveyed annually, but no more territories were identified. The total effort expended was ~15 h, and involved an additional 10 km of track, 8 km of which was at slightly lower altitudes than the regularly surveyed transects.

Border Ranges

Following rationalisation, 15 territories were confirmed on the basis of occupation

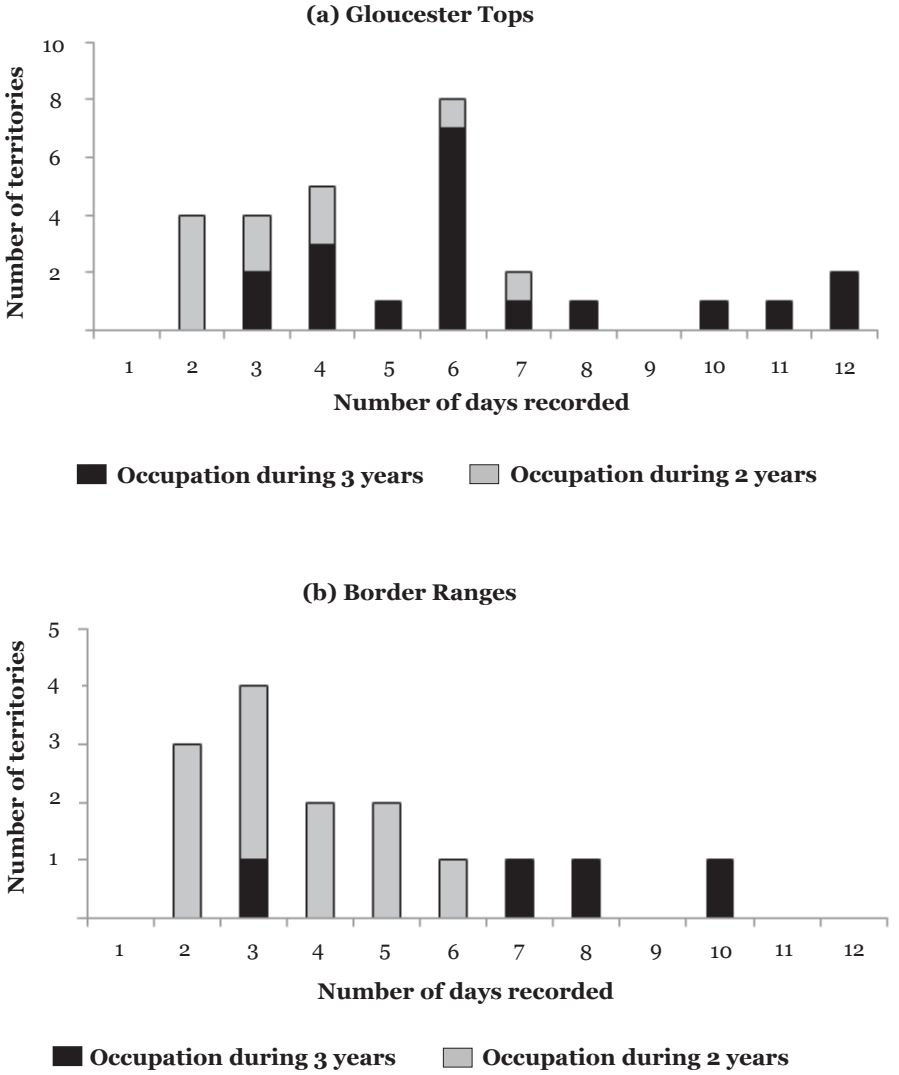

Figure 4. The number of days on which Rufous Scrub-birds were heard calling at the territories in (a) Gloucester Tops and (b) Border Ranges during surveys in 2010–2012.

in at least 2 years (Table 2). Four territories were occupied in all 3 years, and a further two in both 2010 and 2012 but not in 2011; these have been assumed to be permanently occupied in Table 2. If it is assumed that the four territories occupied in both 2011 and 2012 were permanently occupied (i.e. missed during the 2010 surveys, as opposed to being newly established in 2011), the number of permanent territories is 10. A further five territories were recorded in both 2010 and 2011, but

Table 2. Rufous Scrub-bird territories occupied in at least two breeding seasons at the Border Ranges, NSW, in 2010–2012.

Track name	*Distance surveyed (km)*	*No. of territories*			*No. constantly occupied*	*Total territories found*
		2010	*2011*	*2012*	*2010–2012*	
Brindle Creek	4	6	7	6	3[a]	9
Sheep Station Creek	5	3	4	4	3	4
Booyong Walk	3	2	2	0	0	2
Total	**12**	**11**	**13**	**10**	**6**	**15**

[a]Includes two territories with records in 2010 and 2012 but not 2011

not in 2012. These five territories represent 33% of the total number of territories (15). One territory was confirmed in 2010, but there were no subsequent records there. A further 12 records of Scrub-birds based on single records were dismissed as either involving birds attempting to establish territories, or misidentification.

Four territories involved birds calling from locations along extended segments of track, of up to 150 m in length; these have been interpreted conservatively to each be a single territory.

The 10 territories assumed to be occupied throughout the years 2010–2012 were located in seven of the 12 transects. There were single unconfirmed records for three other transects. The highest densities were 3 territories km^{-1} during 2011 in the first and third 1-km transects of the Brindle Creek Track (this includes the implied continuous occupation of a territory with records in 2010 and 2012).

The mean number of days that a territory was confirmed was 4.5, including three territories (27%) which were based on just two records each (Figure 4b).

Two unconfirmed Rufous Scrub-bird territories were found outside the surveyed transects.

Rainfall

Both the study areas are in remote areas with the nearest permanent weather-stations ~20 km distant, at Gloucester–Upper Bowman (280 m asl) and Kyogle Post Office (80 m asl). Although these weather-stations are at much lower altitude than the survey sites, they provide an indication of regional trends in annual and seasonal rainfall (Figure 5). In the first 2 years of this study, 2010 and 2011, annual rainfall exceeded the long-term mean (over 45 and 95 years at Gloucester and Kyogle, respectively) by between 10 and 21% (Australian Bureau of Meteorology

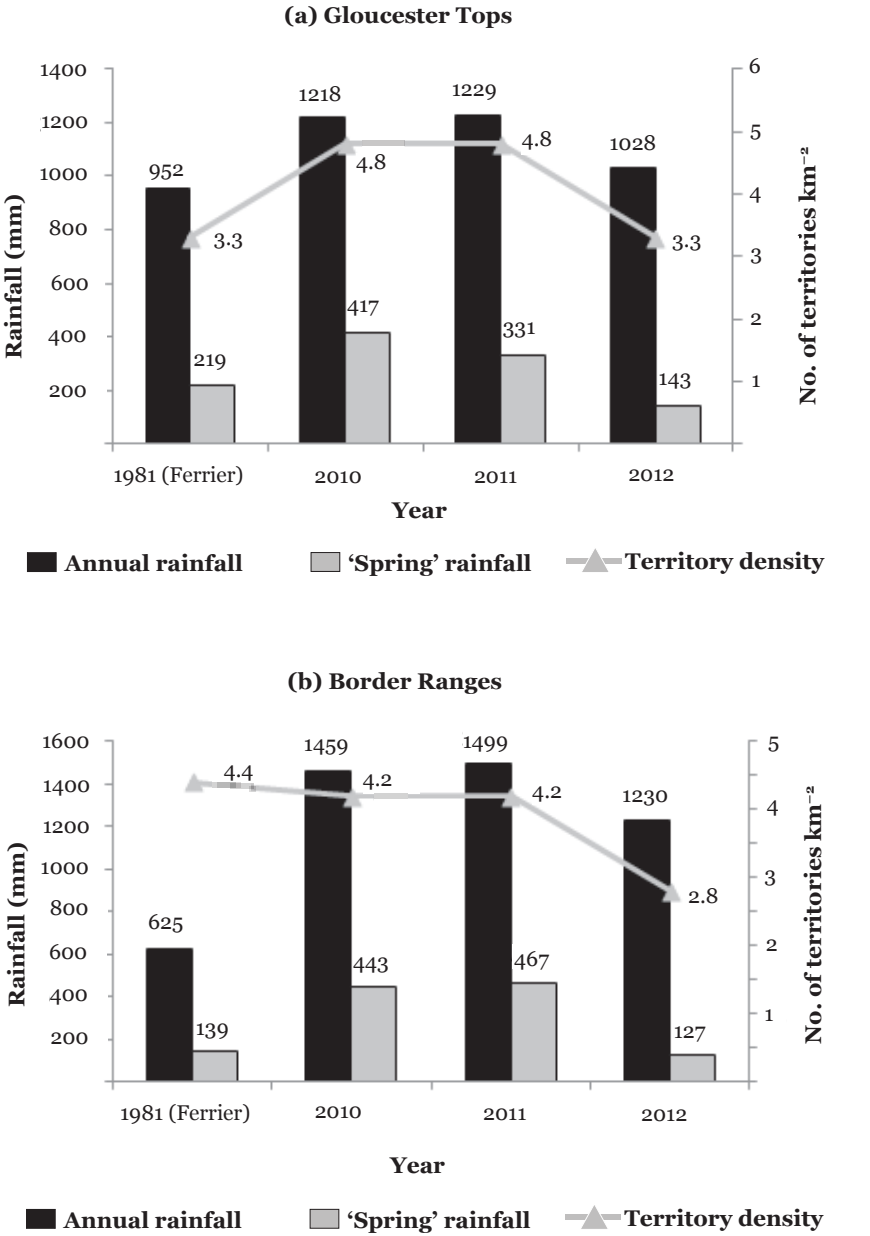

Figure 5. Comparison of variations in Rufous Scrub-bird territory densties with rainfall at (a) Gloucester Tops and (b) Border Ranges. Data on territory densities for 1981 are from Ferrier (1984).

2013). In 2012, the annual rainfall was lower, being near the long-term mean at Border Ranges and 6.9% below the mean at Gloucester Tops. Good 'spring' (defined as the period August–November leading into and during the peak of the Rufous Scrub-bird breeding season) rainfall may be crucial. In 2012, the spring rainfall was 49% (Gloucester Tops) and 50% (Border Ranges) lower than the corresponding long-term mean. In contrast, in 2010 and 2011, spring rainfall was above the long-term mean level (19 and 50% at Gloucester Tops, and 75 and 85% at the Border Ranges, in each year, respectively).

For comparison, the annual and spring rainfall for 1981, the year of Ferrier's baseline studies, are shown in Figure 5, indicating that the spring rainfall then was more comparable with 2012 than with either 2010 or 2011 of our study.

Discussion

In 2010, Rufous Scrub-bird territory densities similar to or exceeding those found in the baseline studies by Ferrier (1984) 30 years earlier were observed in both study areas (Figure 6). This correspondence provided confidence that Scrub-birds could be monitored by teams of volunteers walking transects in a manner similar to that used by Ferrier, highlighting the value of providing detailed methods to allow replication of survey techniques (Lindenmayer *et al*. 2012).

Detection rates

Central to the following discussion is the degree of confidence that can be placed in the detection of all the territorial male Rufous Scrub-birds inhabiting a set of transects. Firstly, there is the issue of the lower detection rates of Scrub-birds in rainforest habitat in the Border Ranges compared with eucalypt forest at Gloucester Tops. Ferrier (1984) found the detection rate was typically ~50% lower in rainforest over a wide range of conditions. This has consequences for the confirmation rates of territories (Figure 4) and perhaps explains why some territories were found in 2010 and 2012 in the Border Ranges, but missed in 2011 (Table 2). Secondly, there is the variation in detection rate with survey conditions such as humidity, wind strength and time of day. Although survey conditions were noted, no attempt was made to correct for variations because previous attempts have provided inconclusive and even contradictory outcomes (Ecological Australia 2009). However, it is important to know when a set of surveys involved unfavourable conditions.

It is also important to gauge whether the survey effort is sufficient to detect all the territories being advertised. Using Ferrier's (1984) predicted probabilities for rainforest, 40% is a conservative estimate of the probability of detecting any individual calling male Rufous Scrub-bird in a single survey, which equates to 87% probability of detecting a given territory during an annual set of four surveys. At Gloucester Tops, a corresponding detection rate of 60% equates to 97% probability of detecting a given territory with a similar survey effort. The net conclusion is that more annual survey effort is required in the Border Ranges, and current protocols may be marginal if conditions are adverse (e.g. rain or high wind). For instance, at Border Ranges, 15 permanent territories were identified (Table 2), but in any year

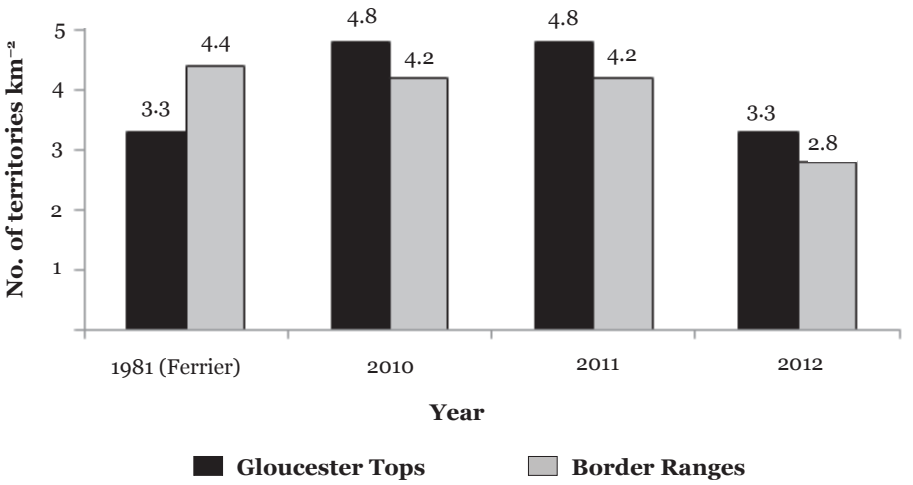

Figure 6. Comparison of Rufous Scrub-bird territory densities found in this study at Gloucester Tops and Border Ranges, NSW (2010–2012) with Ferrier's results in 1981 (Ferrier 1984).

there is a 13% probability that any one of these territories would be missed, which equates to 1.95 territories for the set of 15. This prediction fits extremely well with failure in 2011 to find two territories that were found in both 2010 and 2012. At Gloucester Tops, because of the higher detection rate, only 3% of the 33 permanent territories (Table 1) would be missed, which equates to 0.99, or approximately one territory. This prediction is in reasonable agreement with the results in 2011, when 29 of the 31 territories identified in 2010 were found and two were missed. It also emphasises the anomalous nature of the results for 2012 at Gloucester Tops, when only 20 territories were found and 11 identified in 2011 were missed (Table 1). A possible explanation is that the detection rate fell in 2012, as a consequence of the birds calling less under the prevalent dry conditions; alternatively, the territories may have been abandoned.

Territory densities

Gloucester Tops

At Gloucester Tops, the 29 Rufous Scrub-bird territories located in both 2010 and 2011 surveys equate to a density of 4.8 territories km^{-2}, assuming that all territories located within 150 m either side of tracks were detected. This is slightly higher than the density of 3.6–4.5 territories km^{-2} published previously for the first year of this investigation (Newman & Stuart 2011) because some of the locations tentatively identified in 2010 were confirmed following further surveys in 2011. The fact that 29 of the 31 Scrub-bird territories identified by multiple records in

2010 were again occupied in 2011 (94% continuity of occupancy) and only two new territories were found suggests, firstly, that the Scrub-bird population density was stable between the 2 years (2010–2011) and, secondly, that the survey method was effective in locating the near complete inventory of territories in the study area. It was therefore surprising that in 2012 only 20 (3.3 territories km^{-2}) of the 31 territories occupied in 2011 had calling Scrub-birds (65% continuity of occupancy) and no new territories were located.

Ferrier's (1984) results for Gloucester Tops equate to a density of 3.3 Rufous Scrub-bird territories km^{-2}, which is identical to the level that we found in 2012, but 31% lower than densities found in 2010 and 2011. As 70% of transects were the same as those used by Ferrier, we therefore conclude that there is no evidence for decline in the Scrub-bird population in the Gloucester Tops study area. Indeed, the higher territory densities in 2010 and 2011 suggest there may have been an increase, as discussed below.

Although our transect survey effort was less in 2012 than in previous years, we expended considerable additional effort (e.g. extra time and specific visits) at the territories where we had failed to find Rufous Scrub-birds during the initial 2012 surveys. We believe that we would have found Scrub-birds if they were present and calling with the frequency of previous seasons. Possible explanations for the apparent decline are discussed below, when comparing with the results for the Border Ranges.

Ferrier (1985) found that Rufous Scrub-bird territories were well spaced at Gloucester Tops, typically separated by at least 500 m. He concluded that minimising social interaction and territorial disputes was a key factor determining the distribution of territories in areas of relatively uniform habitat. Ekert (2002) found an increased tendency for clusters of Scrub-bird territories, particularly on the Glowang Track. Our surveys confirm this tendency, with decreased spatial separation of territories (i.e. density exceeding 2 territories km^{-1}) providing evidence of clusters on the Glowang and Carey's Peak Tracks. In addition, some Scrub-bird territories were associated with wetter vegetation at creek crossings, suggesting that territories are now less evenly dispersed than indicated by Ferrier (1985), although this preference for creek edges is not an exclusive prerequisite for territory selection.

Border Ranges

In the Border Ranges, 15 territories were identified over the 3 years (2010–2012), equating to a density of 4.2 territories km^{-2}, which is comparable with that (4.4 territories km^{-2}) recorded by Ferrier (1984), but our surveys involved different and probably more favourable transects than those used by him. The density at Border Ranges (4.2 territories km^{-2}) was slightly lower than at Gloucester Tops (4.8 territories km^{-2}) in 2010 and 2011 (Figure 6). In making this comparison, we have drawn on the aggregate of territories confirmed in any 2 years of the Border Ranges surveys because territories were less frequently confirmed every year. Possible reasons for this difference are now discussed.

If only 10 Rufous Scrub-bird territories were occupied in 2012 (i.e. none were

missed), their density in the Border Ranges falls to 2.8 territories km^{-2}, which is lower than that reported by Ferrier (1984).

Confirmed Rufous Scrub-bird territories were found in seven (58%) transects, which suggests that a significant portion of the area surveyed in the Border Ranges was unsuitable for Scrub-birds. This is surprising because transects selected for this study had the highest Scrub-bird occupancy found by Ekert (Ekert 2005; Ecological Australia 2009). The proposition that much of the habitat there was unsuitable is supported by the absence of any confirmed Scrub-bird territories in three transects (25%) in the Border Ranges compared with one (5%) at Gloucester Tops. Two Border Ranges transects (with four and three territories respectively) had densities exceeding 2 territories km^{-1}.

Comparison of territory densities

Rufous Scrub-bird territory densities at Gloucester Tops and the Border Ranges were similar throughout the 2010–2012 studies, with densities falling in 2012 in both areas (Figure 6). However, the similarity between the territory densities should be treated with caution because, as discussed previously, Border Ranges transects selectively targeted high-grade Scrub-bird habitat.

Thirty years earlier, Ferrier (1984) found territory densities to be 33% higher in the Border Ranges compared with Gloucester Tops (Figure 6). It was not possible to compare our results with the surveys co-ordinated by Ekert (Ekert 2005; Ecological Australia 2009) because of differences in survey methods and objectives, namely a focus on an index of abundance in Ekert's surveys as opposed to measuring territory densities. An analysis by Ecological Australia (2009) supported the conclusion that the southern subspecies *A. r. ferrieri* was more abundant than the northern subspecies *A. r. rufescens*, but rejected evidence of a decline in status between the 1981 and 1999–2004 studies. However, they accepted the possibility that a decline may have occurred but was masked by the variability of the data (Ecological Australia 2009).

In summary, Rufous Scrub-bird territory densities at Gloucester Tops in 2012 were very close to those found there by Ferrier in 1981 (Ferrier 1984) but, based on a similar comparison for these 2 years, densities had fallen by 36% in the Border Ranges. As outlined below, comparisons between 1981 and 2012 are more valid than with other years because of similarities in rainfall patterns in 1981 and 2012.

Territory clusters

In his comparison of Rufous Scrub-bird populations in the two study areas, Ferrier (1985) found that the distance separating territories was a key difference between the two populations. At Gloucester Tops, but not in the Border Ranges, the distance separating territories was considered a critical factor. At Gloucester Tops, suitable habitat (the basic requirements of which are dense ground-cover, moist microclimate and deep leaf-litter: Ferrier 1985) generally occurred in long strips of eucalypt forest fringing the edge of rainforest. Social spacing mechanisms, involving adjacent territory centres separated by at least 250 m, seemed to play a critical role in preventing Scrub-birds taking up territories close

to existing territories in what otherwise may have been ideal habitat. Twenty years later, Ekert (2002) found evidence of clusters of territories, particularly along the Glowang Track. We confirmed this result in the present study, both at Glowang and along the Careys Peak Track, where densities exceeded 2 territories km^{-1} of transect in some transects. This suggests that there have been changes in the spatial distribution of territories at Gloucester Tops.

In the Border Ranges, the habitat is predominantly rainforest, and dense understorey occurs only as isolated patches, usually of insufficient size to support more than one territory (Ferrier 1985). Hence the distribution of territories is determined by the spatial distribution of understorey vegetation rather than social interaction between pairs. This was apparent during our study based on the less even distribution of territories between transects.

Anomalously low detection rates in 2012

At both study areas, there was a decrease of 30–35% in the number of Rufous Scrub-bird territories detected in 2012: nine territories fewer at Gloucester Tops and five fewer in the Border Ranges, compared with previous years (Figure 5). Natural mortality might account for 10% of the loss (four or five birds across both study areas), given that the life expectancy of an adult male is thought to be ~10 years (Ferrier 1985), but in a stable population these birds would be replaced. Survey effort in 2012 was comparable with previous years, except for two territories on the Mt Nelson Track at Gloucester Tops. Consequently, other explanations are required to explain the decreased detection of territories. An obvious difference was the abnormally dry weather entering and during the breeding season of 2012 (see 'spring' rainfall levels, Figure 5), following a number of years of wetter than normal conditions. Ferrier (1984) showed that the detection of calling Scrub-birds decreased with decreasing humidity. Thus, under dry conditions in 2012, territories on the edge of the detection limit from tracks may have been missed. However, this does not explain many of the territories where Scrub-birds were now undetected. It is also possible that Scrub-birds suspend breeding activity and call less during dry conditions, which would again decrease detectability. Another possibility is that under dry conditions the territories are either temporarily or permanently abandoned and the males disperse to forage elsewhere.

We tentatively suggest that low 'spring' rainfall in the period entering and during the breeding season may be more important than the annual rainfall. If this hypothesis is correct, Ferrier's 1981 studies (Ferrier 1984) best relate to our 2012 studies (compare 'spring' rainfall in Figure 5), as discussed previously. In addition, the total rainfall levels in 1981 were lower than in any of the years during our study.

Future survey options

The ongoing challenge is to confirm whether known Rufous Scrub-bird territories continue to be occupied and whether any new territories are established. It is proposed that each of the existing transects continues to be walked at least twice annually during the morning when all bird species are active, with additional visits

if necessary to any previously known territories which have not yet been confirmed in the current year. However, in view of the new knowledge that Scrub-birds may sing more frequently early and late in the day (Stuart *et al*. 2012), supplementary visits to apparently unoccupied territories should be made at other times where logistically possible. Opportunistic observations by the Border Ranges team suggest that late-afternoon surveys are beneficial, as noted by Ekert (2002).

Implications on status of Rufous Scrub-bird

The Rufous Scrub-bird has always been rare since European settlement, being restricted to limited amounts of specialised habitat (Smith 1977). Smith concluded that species with the longest evolutionary history (such as Scrub-birds) had the smallest distributions and abundance. He also concluded that since settlement the activities of Europeans (fire practice, agricultural clearing and forestry) have been more important to the further decline of this species than have climatic changes. Ferrier (1984, 1985) located 174 territories during his studies in the early 1980s of the remnant Scrub-bird populations and concluded that, as most of the habitat existed in national parks and state forests, passive conservation management (namely the reservation of land and prevention of harmful influences: see Halliday 1978) should be appropriate. However, he pointed out that the Scrub-bird generally occupies forest at an intermediate successional stage following disturbance through fire or opening of the canopy. Hence, forest management practices may be important to habitat suitability (Ferrier 1985). In Ferrier's baseline studies, forest practices were thought to have had variable impacts on the suitability of Scrub-bird habitat. At Wiangarie State Forest (now the Border Ranges National Park), selective logging was postulated to be beneficial, opening up the canopy and allowing understorey development. In contrast, at Gloucester Tops, logging in eucalypt forest appeared to be detrimental. At Gloucester Tops, Scrub-bird territories were sufficiently wet to survive mild hazard-reduction burns and Scrub-birds maintained territories adjacent to burnt areas. Ferrier (1985) expressed concern over the potentially adverse impact of intense wildfires. We note that a fire in 2009, which burned an extensive area immediately below the Kerripit Road transects, destroyed some known Scrub-bird habitat; no Scrub-bird territories were found in this area during the present study.

Ferrier (1984) also suggested that climate change could cause a retreat of Rufous Scrub-bird populations to higher altitudes. Ekert (2002) echoed this concern, suggesting that the emerging tendency to form clusters of territories might be a consequence of altitudinal retreat.

At Gloucester Tops, the density of Rufous Scrub-bird territories found in 2010 and 2011 exceeded the baseline levels 30 years earlier, suggesting that, at least in this core habitat, the Scrub-bird population might be increasing. However, the decreased detection of Scrub-birds in previously occupied territories in the dry breeding season of 2012, the clustering of territories, and failure to find any territories at lower altitude and in an area burnt by wildfire all suggest that changes may be occurring in the suitability of habitat, particularly under dry conditions.

In the Border Ranges, Rufous Scrub-bird densities were comparable with those

30 years earlier other than during the dry conditions of the 2012 breeding season. However, although Ferrier (1984) described rainfall patterns during his study as normal, we suggest that there was below-average rainfall in spring, making the 1981 and 2012 results comparable, and indicating a decline in the Scrub-bird's status in the Border Ranges. The bias caused by selecting transects involving superior Scrub-bird habitat may have exaggerated the magnitude of our 2012 territory density, in which case the evidence for decline becomes stronger.

The contrasting conclusions drawn concerning the status of the two populations of Rufous Scrub-birds are interesting, presumably relating to differences in habitat (eucalypt forest at Gloucester Tops and rainforest in the Border Ranges). The possibility of an increase in territory density at Gloucester Tops is consistent with the concept of altitudinal retreat in which the remnant population is forced into increasingly small islands of montane habitat (Watson 2010). However, cessation of logging and lower fire frequency at Gloucester Tops during the last 30 years may have impacted favourably on the Scrub-birds. The apparent decline in the Border Ranges is tentatively attributed to the rainforest habitat becoming less suitable following the cessation of selective logging, which opens up the canopy and facilitates the growth of dense understorey vegetation essential to the existence of Scrub-birds (Ecological Australia 2009). Infrequent *ad hoc* observations over the past 30 years suggest that the extent of suitable Scrub-bird habitat on the Tweed Range (Wiangarie) has dropped dramatically following the cessation of logging (S. Ferrier pers. comm.).

A future challenge is to integrate knowledge generated from ongoing monitoring in progress across the entire set of IBAs supporting Rufous Scrub-bird populations and relate this to other studies which provide insights into changes in the status of the species (Ferrier 1984; Ecological Australia 2009; Williams 2012).

Conclusions

Use of experienced volunteers walking linear transects through suitable habitat listening for calling males during the breeding season is an effective method of locating Rufous Scrub-bird territories. At the Gloucester Tops and Border Ranges study areas, respectively, 29 and 15 territories occupied in at least 2 years were located along 20 and 12 km of tracks. In 2012, no calling was detected at 30–35% of these territories (nine at Gloucester Tops and five in the Border Ranges). The decreased detection of Scrub-birds during 2012 is attributed to the abnormally dry conditions, particularly in August–November, immediately before and during the breeding season. The extent to which this is a consequence of decreased detectability of Scrub-birds caused by low humidity is uncertain. However, a decline in density of breeding males is also possible. Ongoing monitoring is essential to determine whether the difference is real, temporary, or permanent.

It is encouraging that Rufous Scrub-bird territory densities are of similar magnitude to Ferrier's 1981 baseline levels (Ferrier 1984, 1985). This suggests there has been limited change in the species' status over a 30-year period, at least in core habitat. However, this conclusion may need to be tempered for several reasons in addition to the decreased detection of territorial males in 2012. The monitored

populations are in core high-altitude habitat and cover a small proportion of the Scrub-bird's range. Populations at lower altitude are less numerous and may be more sensitive to a change in status. It is therefore of concern that the limited attempts that we made to locate Scrub-birds outside the core high-altitude habitat were unsuccessful. At Gloucester Tops, where a slight increase may have occurred, there is an increased tendency for territories to be more closely clustered, which suggests that changes may have occurred in the structural suitability of the habitat for Scrub-birds. In contrast, in the Border Ranges there may have been some decline in status.

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