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Rufous Scrub-birds *Atrichornis rufescens* in the Gloucester Tops of New South Wales: Findings from surveys in 2010–2016

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Abstract. An isolated population of Rufous Scrub-birds *Atrichornis rufescens* in a high-altitude area of the Gloucester Tops, New South Wales, was surveyed annually in spring in 2010–2016. The 5000-ha study area formed part of the Barrington Tops and Gloucester Tops Key Biodiversity Area (KBA). The Rufous Scrub-bird, which was the trigger species for the KBA nomination, was found to have a widespread distribution in the study area. Thirty-seven territories were identified; 20 of them had long-term occupancy, with records from at least three successive years and, in most cases, records from all or most years. The other territories were more transitory, occupied for 1–2 years but then with no further records or else a long gap between records. Rufous Scrub-birds were not detected in an area of their former habitat that had been burnt in a major fire until 6–7 years after the fire. Usually, the Scrub-bird territories were well-spaced, with separations of ≥300–400 m between their centres. Under favourable conditions, territories were sometimes clustered more closely together, but this seemed not to be sustainable: in each case, one of the clustered territories eventually was abandoned. Rufous Scrub-bird territory densities in the Gloucester Tops survey area were in the range 3.3–4.0 territories km^{-2}, similar to previously reported 1981 baseline levels, which suggests that there has been limited change to the species' status within an area of core high-altitude habitat over a 35-year period.

Introduction

The Rufous Scrub-bird *Atrichornis rufescens* is classified as Endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and the IUCN Red List, and as Vulnerable under the New South Wales *Threatened Species Conservation Act 1995*. It is a species that appears to be affected by altitudinal retreat, in which the remnant population is forced into increasingly small islands of montane habitat (Watson 2010). The populations of both the northern (*A. r. rufescens*) and southern subspecies (*A. r. ferrieri*) are suspected to be in decline (Garnett *et al.* 2011). One of the locations of the five remnant Rufous Scrub-bird populations is the Gloucester Tops in New South Wales.

The Gloucester Tops form the eastern part of the Barrington Tops National Park. In 2009, they were included in a newly designated Important Bird Area (IBA), the Barrington Tops and Gloucester Tops IBA (Dutson *et al.* 2009). The Rufous Scrub-bird was the trigger species for the nomination. More recently, IBAs have been redesignated as Key Biodiversity Areas (KBAs) in order to extend the concept to non-avian threatened species (BirdLife Australia 2017). The boundaries and general location of the Barrington Tops and Gloucester Tops KBA are presented in Figure 1, which also indicates the area covered in the present study.

Monitoring the status of trigger species is a requirement of the IBA/KBA process (Dutson *et al.* 2009). A 5000-ha (radius 4 km) high-altitude area of the Gloucester Tops that historically was known to include core habitat for Rufous Scrub-birds (Ferrier 1984, 1985; Ekert 2002, 2005; Williams 2012) was selected for detailed study (Newman & Stuart 2011; Newman *et al.* 2014). All of the study area, situated ~35 km from the town of Gloucester, was >1100 m in altitude and was mostly >1200 m above sea-level. Interim findings from the first 3 years of surveys have been presented previously (Newman *et al.* 2014); the current paper presents a detailed analysis with important insights into the dynamics of Rufous Scrub-bird territory occupancy from 2010 to 2016.

Methods

Study area

Two main habitat types are in the study area, characterised by their principal types of vegetation: Antarctic Beech *Lophozonia moorei* rainforest (Heenan & Smissen 2013), and open eucalypt forest comprising mainly Messmate *Eucalyptus obliqua* and Brown Barrel *E. fastigata* (Binns 1995). These two habitats occur as a mosaic throughout the study area, with some sections of Snow Gum *E. pauciflora* open woodland also present (Binns 1995). The Antarctic Beech rainforest is characterised by an open understorey of ferns and Bracken *Pteridium esculentum*, whereas the eucalypt forests have a dense understorey of *Lomandra* species, grasses, Bracken, fallen timber and leaf-litter. Ferrier (1984) provided detailed descriptions of the vegetation in the areas supporting Rufous Scrub-birds.

Surveys

Surveys were carried out by teams of volunteers at the Gloucester Tops in the Barrington Tops National Park (32°05′S, 151°36′E) between September and November annually in 2010–2016. The timing of the surveys coincided with the breeding season for Rufous Scrub-birds, when calling males are most reliably detectable (Ferrier 1984). The annual survey program objectives were achieved during one–two campouts supplemented by day visits.

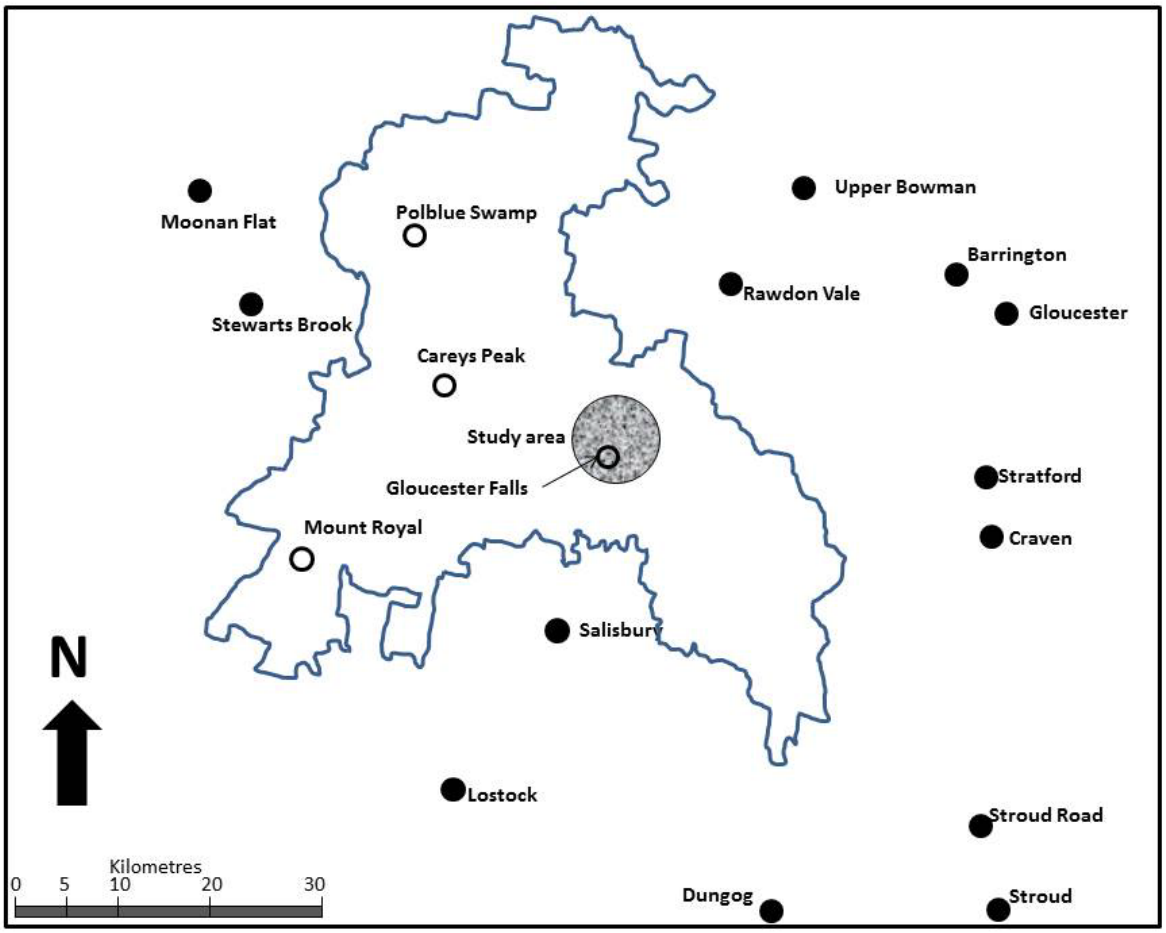

Figure 1. Barrington Tops and Gloucester Tops Key Biodiversity Area and the study area (shaded).

Within the 5000-ha study area, 21 1-km transects were established along roads and walking tracks (Figure 2; see Table 2 for identity codes of transects), and were measured either by odometer readings where car access was possible or by measurement on Google maps, using GPS units set to the WGS84 coordinate system. All transect segments were marked at their extremities with coloured tape. The selected transects corresponded with ~80% of the area surveyed for Rufous Scrub-birds by Ferrier (1984) and also with several of the fixed survey sites used in the Birds Australia Rufous Scrub-bird study led by Ekert (Ekert 2002; Eco Logical Australia 2009).

Twenty transects were surveyed in 2010–2012, with one additional transect (GT3A) added in 2013 (see later discussion). In 2015 and 2016, because of resource constraints, the monitoring program was reduced, to focus on 11 of the 21 transects (the five Kerripit Road transects, the five Gloucester Tops Road transects and the first kilometre of the Careys Peak transects).

Under favourable conditions (in particular, low wind), calling male Rufous Scrub-birds can be heard from a distance of 150 m (Ferrier 1984), although detectability declines with distance and potentially might lead to under-estimations. Thus, each transect surveyed a 300-m-wide section of the study area, i.e. an area of 30 ha. Collectively, 630 ha were sampled over all 21 transects, representing 12.6% of the overall study area in the Gloucester Tops.

The 1-km transects were surveyed by one–three people (typically two people), with at least one person being

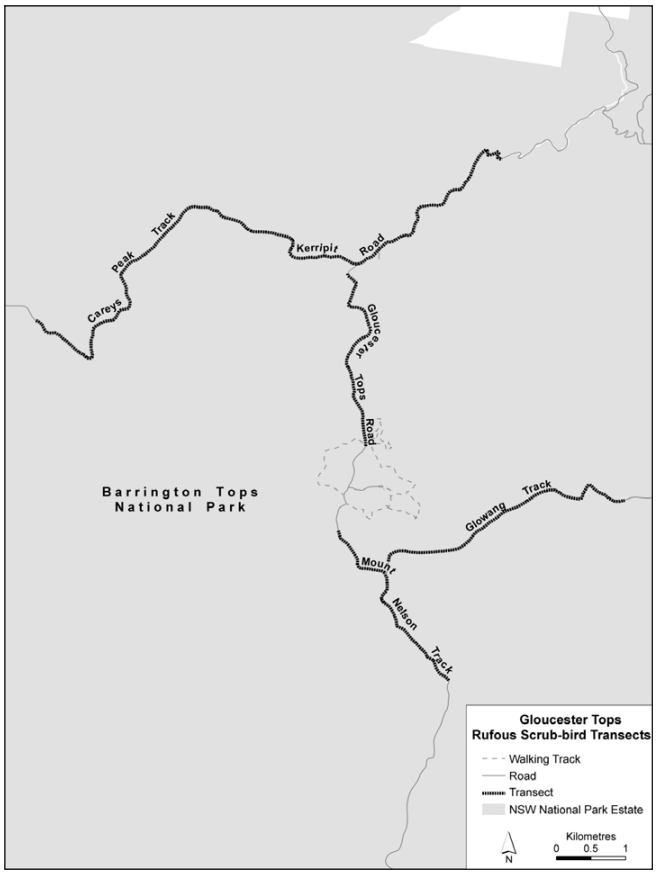

Figure 2. The main sets of transects in the Gloucester Tops, New South Wales, study area (from Newman *et al*. 2014).

experienced in the survey methodology and also being familiar with the calls of Rufous Scrub-birds. Continuity of involvement of core participants was good. All bird species encountered during the surveys were recorded; an overview of the results for all species is provided by Stuart & Newman (2018). Surveys were done only when conditions were favourable (low–medium wind, zero–low rainfall). They commenced at *c.* 0800 h and took 4–6 h to complete. Typically, *c.* 1 h was spent in each transect, although the actual time varied depending on whether any Scrub-birds were located. Each surveyed 1-km transect was visited at least four times each spring, except for the second and third kilometres of the Mount Nelson Track and the final transect of the Careys Peak Track, which were more difficult to access and were visited only two–three times each spring. For three sets of transects (Careys Peak, Glowang, Mount Nelson), each survey involved two passes through a transect, i.e. outbound and then inbound 1–3 h later. Less time was devoted to surveying during the inbound passages (unless a Scrub-bird was detected), and the total time spent in the transect remained *c.* 1 h.

The core objective of the monitoring program was to locate and confirm Rufous Scrub-bird territories. Whenever Scrub-birds were found, additional time was spent at the location to determine the types of calls used, the persistence of calling, and the number of Scrub-birds present in instances of apparent clustering. 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. Rufous Scrub-birds use a variety of calls and their repertoire includes mimicry. Sometimes it could be difficult for surveyors to be completely certain that they were listening to a Scrub-bird. However, a characteristic call described as 'chipping' is very distinctive for experienced surveyors. When at a location where a Scrub-bird was suspected to be present, surveyors were requested to wait up to 10 minutes to listen to the range of calls made. Only records involving the chipping call were treated as confirmed records of a Rufous Scrub-bird.

All confirmed and unconfirmed records of Rufous Scrub-birds were entered into a database including the precise GPS location for the surveyor's position on the road or track at the time of the record, and the direction and estimated distance between observer and bird. Surveyors were trained to find the spot on the road or track where the Scrub-bird was considered to be orthogonal to their own position. Records were grouped according to their latitude and longitude within each of the 21 transects. Territory status was assigned to sites where there were two or more confirmed records of a Scrub-bird at the same location separated by >4 weeks in the same season or from two consecutive years. Records separated by >3 seconds of latitude or longitude in observer position were not grouped in the same territory. Territories that were confirmed to be occupied in three or more consecutive years were assigned as being long-term territories. Reporting Rates (i.e. the number of Scrub-bird records divided by the number of surveys conducted, expressed as a percentage) were calculated for various time periods.

Table 1. Reporting Rates (RR, %) for Rufous Scrub-birds in 2010–2014, Gloucester Tops, New South Wales. CV = Coefficient of Variation.

5-year RR	*Year*					*CV*
	2010	*2011*	*2012*	*2013*	*2014*	
52.9	50.6	50.7	57.1	43.1	68.8	18

Results

Rufous Scrub-birds were recorded in 20 of the 21 survey transects. Only the transect CP2 had no Scrub-bird records during the surveys. However, a female was observed in CP2 in May 2012 (i.e. outside the time frame of the breeding-season surveys). This bird was 20–30 m from the boundary with transect CP3 (AS pers. obs.).

The average Reporting Rate (RR) for Scrub-birds was 56.5% over the 7 years of spring surveys. Table 1 shows the RRs for the period 2010–2014, during which 20–21 1-km transects were surveyed annually. In that period, the average RR was 52.9%, and the Coefficient of Variation (CV, sometimes termed the relative standard deviation) for RRs was 18%, with the lowest annual RR (43.1%) occurring in 2013.

Between 20 and 32 Rufous Scrub-bird territories were identified each year in 2010–2014, when either 20 or 21 km of transects were surveyed. Twelve and 13 territories were identified in the 2015 and 2016 surveys respectively, when only 11 km of transects were surveyed. In total, 37 Scrub-bird territories were found. Table 2 summarises the number of territories found annually in each transect.

Ten of the 21 transects were surveyed in every year in 2010–2016; the total number of territories found annually in these 10 transects is shown in Table 3.

Twenty territories were classified as having long-term occupancy, with records of a Scrub-bird for at least three consecutive seasons within the 7 years of survey effort. Most of the long-term territories had records spanning five–seven seasons. The numbers of long-term territories identified in each transect are shown in Table 2.

For those territories that were close together, the distances between them are shown in Table 4.

Discussion

Reporting Rates

The study area in the Gloucester Tops was chosen because it was known historically to be core habitat for Rufous Scrub-birds, and the survey method was designed specifically for them. Therefore, it is not surprising that this species is well represented, with an average RR of 56.5% over the 7 years of spring surveys. The low CV (18%) for the surveys in 2010–2014 suggests that the survey method was robust and able to withstand changes to the survey teams from year to year. The RRs for 2015 and 2016 were

Table 2. Number of Rufous Scrub-bird territories in individual 1-km transects in 2010–2016, Gloucester Tops, New South Wales. NA = the transect was not surveyed; long-term = territories occupied for ≥3 consecutive years.

Transect		*Year*							*Long-term*
Group	*Code*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	
Careys Peak Track	CP1	3	3	2	2	3	2	2	2
	CP2	0	0	0	0	0	NA	NA	0
	CP3	3	4	2	2	2	NA	NA	1
	CP4	2	1	1	2	2	NA	NA	1
	CP5	1	1	1	1	1	NA	NA	1
Kerripit Road & extension	KP1	1	1	0	0	1	0	1	0
	KP2	2	2	2	2	2	2	2	2
	KP3	2	2	1	1	1	1	1	1
	KP4	1	1	1	0	1	1	0	1
	KP5	0	0	0	0	0	0	1	0
Gloucester Tops Road	GT1	2	1	1	1	1	1	1	1
	GT2	2	1	0	0	0	0	0	0
	GT3	0	0	0	0	0	1	1	0
	GT3A	NA	NA	NA	2	2	2	2	1
	GF1	2	2	2	1	2	2	2	2
Mount Nelson Track	MN1	2	2	2	1	1	NA	NA	1
	MN2	1	2	0	0	0	NA	NA	0
	MN3	1	1	0	0	0	NA	NA	0
Glowang Track	GW1	3	3	2	1	2	NA	NA	2
	GW2	1	2	2	2	2	NA	NA	2
	GW3	3	3	3	2	2	NA	NA	2
Total no. territories		32	32	22	20	25	12	13	20
No. transects		20	20	20	21	21	11	11	
No.territories/km		1.6	1.6	1.1	1.0	1.2	1.1	1.2	

not readily comparable with previous years because they were from only a subset of transects.

Total and annual numbers of Rufous Scrub-bird territories

Over 7 years of spring surveys, in total 37 Rufous Scrub-bird territories were identified. In most transects, there were also records of Scrub-birds at locations that did not meet the criteria for a confirmed territory. As indicated in Table 2, only the CP2 transect had no territories; however, in several other transects (KP5, GT3, MN2 and MN3) territories were confirmed to be occupied in only 1–2 years. Most other transects had one or two territories each year. Between 20 and 32 territories were found annually in 2010–2014, reducing to 12–13 territories in 2015–2016 when the survey effort was wound back.

The areas with the greatest numbers of Rufous Scrub-birds were along the Glowang Track (which regularly had a total of six–eight territories in its three 1-km transects) and along 3 km of the Careys Peak Track (transects CP1, CP3, CP4), where five–eight territories in total were found each year. Presumably the reasons for this were related to habitat but such analysis is beyond the scope of this paper.

Table 3. Number of Rufous Scrub-bird territories in the 10 transects surveyed annually in 2010–2016, Gloucester Tops, New South Wales.

	Year						
	2010	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
No. territories	15	13	9	7	11	10	11
No. territories/km	1.5	1.3	0.9	0.7	1.1	1.0	1.1

Table 4. Estimated separation between centres of Rufous Scrub-bird territories for transects with ≥3 territories, Gloucester Tops, New South Wales. See Table 2 for transect codes; territories are numbered T1–T4.

Transect	*Estimated distance between centres of territories (m)*			
	T1–T2	*T2–T3*	*T1–T3*	*T3–T4*
CP1	200–250+	300–350	~500	
CP3	100–150	220–240	240–260	~500
GW1	200–250	280–300	~500	
GW3	350–400	~100	~400	

Territory occupancy by Rufous Scrub-birds

Not all territories were confirmed to be occupied every year. Occupancy was usually confirmed through hearing a calling male Rufous Scrub-bird at the same general location over an extended period of time (≥4 weeks between records at the same location). Occasionally there were sight records. In the instances where a bird could not be detected at a previously occupied territory, it was not possible to differentiate between the scenarios of the bird being absent and the bird being present but not calling. Sometimes it was possible to resolve this dilemma by making repeated visits to a particular location and/or by listening at the location for extended periods of time. Twenty transects had at least one territory in at least 1 year, and ten transects had two or three territories that were occupied for at least 5 of the 7 years of surveys.

Thirty-two Scrub-bird territories (out of 37 identified overall) were found in both 2010 and 2011, but there were fewer in subsequent years. Several factors might have affected how many territories were located each year:

1. Birds were seldom seen and they called unpredictably. In the more distant (and hence less accessible) transects, surveyors might not have had enough time available to detect the Scrub-bird if it was calling only intermittently.
2. Unpredictability of detecting birds in territories located at some considerable distance (e.g. >100 m) from the road or track. In such cases, the farthest extremity of the territory might have been out of earshot when conditions were unfavourable (e.g. high wind: Ferrier 1984).
3. Birds ceasing to advertise their territories when spring weather conditions were unfavourable for breeding success. In 2012 and 2013, conditions in spring in the Gloucester Tops were very dry (see Newman *et al.* 2014 for an expanded discussion about the 2012 conditions).
4. Changing local conditions rendering some territories no longer suitable for Scrub-birds or, conversely, the habitat becoming suitable where previously it was not so.
5. The death or departure of a Scrub-bird and a subsequent time-lag before another Scrub-bird occupied the territory.
6. In addition, there was some variation in annual survey effort, with a new transect (GT3A) added in 2013 and surveys suspended for 10 transects in 2015–2016.

Results from a subset of transects (surveyed every year, 2010–2016)

Ten of the 21 transects were surveyed in every year in 2010–2016. These transects were easily accessed, allowing surveyors to spend more time listening for 'missing' Rufous Scrub-birds. Moreover, as only three of the territories in them were far from the road or track, there should have been fewer issues about detecting most of the Scrub-birds there if the birds were present and calling. Thus, the effects from variables (1) and (2) above can be mitigated by restricting analysis to these 10 transects. The results are summarised in Table 3. Overall, 17 territories were identified in this subset of transects in 2010–2016, of which two were identified for the first time in 2016.

For the subset of transects, in 2012 only 60% of the 15 territories from 2010 were confirmed to be occupied. In 2013, the confirmed occupancy fell further, to <50% of the 2010 value. Both seasons were characterised by unusually low rainfall, which is thought to cause Scrub-birds to cease advertising their territories or perhaps to abandon them (Newman *et al.* 2014). Occupancy rates recovered in 2014–2016, which had normal spring-rainfall patterns. However, they did not recover to the levels of 2010–2011 (see Table 3). The reasons for this are unclear, although three of the missing birds were from territories relatively far from the road or track, possibly with most of the territory beyond the 150-m distance over which Scrub-birds can reliably be heard (Ferrier 1984). Another contributing factor might be that in 2009 a fire destroyed known Scrub-bird habitat along Gloucester Tops Road, including in the KP5 transect and farther north. Possibly some Scrub-birds had fled from fire-damaged territories and were attempting to establish new territories in unburnt areas in 2010.

Long-term and shorter-term occupancy of territories

Nine of the territories in the subset of 10 transects that were surveyed every year in 2010–2016 had long-term occupancy by Rufous Scrub-birds. Indeed, in seven of them, Scrub-birds were recorded every year, and usually there were many records throughout each season. For the two other long-term territories, there were records from 5 out of the 7 years. Of the eight territories that were not confirmed to be occupied long-term, three were quite distant from the track, as previously noted, and the Scrub-birds might have been present but not detected. Two others were occupied for the first time in 2016 and their continuity of occupancy is yet to be established. The three remaining territories were occupied only in 2010 and/or 2011.

The pattern appeared to be a mixture of long-term territories and territories occupied for shorter periods (1–2 years). A similar pattern was discernible in the results for all 21 transects, where 20 of the 37 identified territories exhibited long-term occupancy and the remainder could not be confirmed to be occupied each year (Table 2). A possible interpretation is that some territories provided very favourable habitat, such that Scrub-birds in those territories were long-lived and/or were quickly replaced by another Scrub-bird in the event of the original bird's demise, whereas other territories provided more marginal habitat. In those more marginal territories, Scrub-birds appear to have remained only while the local conditions were favourable. A recommended future direction for research would be to investigate what makes some territories more favourable than others for this species.

With 20 of the 37 territories (54%) demonstrating long-term occupancy, including nine of 17 territories (53%) in the subset of transects, the situation in the Gloucester Tops was similar to that observed for the New England Rufous Scrub-bird population, where 56% (9 of 16) territories were found to be occupied long-term (from Table 2 in Andren 2016).

The generation time for the Rufous Scrub-bird has been estimated at 4.9 years (Garnett *et al.* 2011), derived from an age at first breeding of 2.0 years and maximum longevity of 7.8 years, both values extrapolated from data for the Noisy Scrub-bird *A. clamosus*. Some territories in the present study had Rufous Scrub-birds present every year for 7 years. Thus, either the generation time is longer than thought, or the territories were quickly re-occupied by another Rufous Scrub-bird upon demise of the original bird.

Territory separations and clustering

Generally, there were one or two Rufous Scrub-bird territories found annually in each transect. However, four transects sometimes had three territories, and in transect CP3 four territories were found in 2011 (see Table 2). Ferrier (1985) found that the distance separating territories in the Gloucester Tops was driven by social spacing mechanisms. He concluded that separations of ≥250 m between centres of adjacent territories seemed to play a critical role in preventing Scrub-birds taking up territories close to existing territories in what otherwise might have been ideal habitat. In the present study, all transects with only one or two territories met Ferrier's (1985) condition, with inter-territory separations of ≥300 m. Usually the separation between territory centres was >400 m. For the four transects with three or more territories in some years, sometimes the inter-territory separations were <300 m (Table 4), as discussed below. Ekert (2002) found evidence of clusters of territories, particularly along the Glowang Track. The present study confirms this finding, for some territories in some years along the Glowang and Careys Peak Tracks.

Three territories in transect CP1 were clustered within a radius of 500 m. One of them did not have long-term occupancy; it was confirmed to be occupied only in three of the seven seasons. In transect CP3, three territories were clustered; one was occupied only in 2010, and another only in 2010–2011, whereas the third territory had long-term occupancy. Two territories in transect GW1 were close together but one was occupied in only 2010–2011 whereas the other had long-term occupancy. Transect GW3 had two territories very close together (estimated separation ~100 m: Table 4) in 2010–2012; after that, there were no further records at one of them.

Overall, there seem to have been circumstances (e.g. favourable local conditions), where Scrub-bird territories became clustered, leading to there being territories located within a proximity which would result in increased territorial conflict when males call. However, this appears to have been only a short-term situation. Ferrier's (1985) social spacing mechanism, leading to territories separated by >250 m, appeared to hold as the norm.

When territory clustering was identified initially (Ekert 2005) and confirmed (Newman *et al.* 2014), it was assumed to be a new phenomenon associated with altitudinal retreat (Ekert 2005) or decreased uniformity of habitat (Newman *et al.* 2014). It now appears to be an intermittent phenomenon that might not have been apparent in Ferrier's (1984) study during only two breeding seasons. Consequently, it might be the normal process by which the population density is regulated at its optimal holding capacity in this type of core habitat and does not reflect any mechanistic change during the last 35 years.

Rufous Scrub-birds re-occupying a previously burnt area

None of the Rufous Scrub-bird territories found in 2010–2014 was from an area along a *c*.2-km stretch of Gloucester Tops Road where both Ferrier (1984) and Ekert (2005) had found Scrub-birds. That section of Gloucester Tops Road, which included the KP5 transect and area to the north of it, was burnt in a fire in 2009 (Newman *et al.* 2014) and apparently became unsuitable for Scrub-birds. Initially there was very little ground-cover in the burnt area (AS pers. obs.). The area was periodically checked in 2010–2014 but no calling male Scrub-birds were detected.

In 2015 and 2016, some Scrub-birds moved back into the burnt area. In 2015, a calling male was detected several times over 3 weeks in September–October ~500 m north of the end of the KP5 transect (i.e. beyond the set of transects regularly surveyed). The presence of a permanent territory here could not be confirmed as the site was not revisited in 2015. A Scrub-bird was not found at this location on several visits during spring 2016. Instead, a male was regularly present at another site ~1 km south of the first location. The location was within the KP5 transect, again in the area that had been burnt in 2009. It was confirmed that a permanent territory had been established, with several records of the bird obtained over 6 weeks during the 2016 breeding season.

The habitat at both sites consisted of tree-ferns such as Prickly Tree-fern *Cyathea leichhardtiana* and tall shrubs such as *Acacia* species (Binns 1995). Although some ground-cover was present, the continuum of dense ground-cover, leaf-litter and fallen timber that characterises Scrub-bird territories elsewhere in the Gloucester Tops had not formed. Both sites had many tree-ferns, and these presumably were important for providing shelter for the Scrub-birds. The Werrikimbe and Border Ranges populations of Rufous Scrub-birds in northern New South Wales and Queensland are reported to utilise habitat comprising many tree-ferns (P. West pers. comm.; F. Hill pers. comm.).

Unfortunately, the same general area of the Gloucester Tops was burnt again in late November 2016, in a fire that was started by a lightning strike (P. Beard pers. comm.). From an inspection of the area in mid December 2016, the 2015 Rufous Scrub-bird site was found to be badly burnt. The entire understorey had gone; seemingly it will be many years before it again becomes suitable for Scrub-birds. For the 2016 Scrub-bird territory, everywhere that the bird had been recorded was burnt. However, the area immediately adjacent (which had the same habitat) escaped the fire so possibly the Scrub-bird was able to flee and survive. The bird was not detected in three visits to the area in the summer of 2016–2017, although Scrub-birds call less frequently in summer (Ferrier 1984; Stuart *et al.* 2012). The site will be monitored closely in the spring 2017 surveys (see note added in proof, p. 20).

This observation places on record the lengthy time spans that are involved for Rufous Scrub-bird habitat to recover after fire.

Population densities and population estimates

For the entire set of transects, the average number of advertised Rufous Scrub-bird territories per 1-km transect was 1.25 in 2010–2016 (annual range 1.0–1.6 territories/km: see Table 2). However, this average included two exceptional years (2010 and 2011), where more territories were found than in any other year. For the other 5 years, an average of 1.1 territories/km was confirmed to be occupied (range 1.0–1.2 territories/km). The same result (an average of 1.1 territories/km) was obtained for the subset of 10 transects that were surveyed every year (Table 3).

This is equivalent to a density of 3.6 territories km^{-2} (range 3.3–4.0 territories km^{-2}), assuming that all territories located within 150 m each side of the track were detected. The calculated density from the present study aligns well with Ferrier's (1984) Gloucester Tops results which equated to a density of 3.3 territories km^{-2}. This finding suggests that the Rufous Scrub-bird population in an area of core habitat for them in the Gloucester Tops has at a minimum remained stable over the three-decade interval between Ferrier's (1984) study and the present one.

The territory density range of 3.3–4.0 territories km^{-2} found in the present study places the local population range for the 5000-ha study area (Figure 1) at 167–200 pairs. This estimate is based on the assumption that the 21 transects surveyed were representative of the 5000-ha study area. Although it was only possible to survey along existing tracks because of the dense vegetation, the transects sampled ~12.6% of the Figure 1 study area and included all the key aspects of the area (e.g. following water courses, steep slopes and ridges) so it seems very likely that they were representative.

Ferrier (1984) estimated the population of the southern subspecies *A. r. ferrieri* at 1720 pairs. Known sub-populations of this subspecies are centred on Barrington Tops (including the Gloucester Tops), Hastings Range (including Werrikimbe National Park) and Dorrigo/Ebor (New England National Park). The Scrub-bird population is believed to have declined since 1984 (Garnett *et al.* 2011). Thus, the 5000-ha study area (Figure 1) was found to hold ≥10% of the total population of the southern subspecies of the Rufous Scrub-bird.

Surveys for Rufous Scrub-birds outside the core habitat

When resources permitted, some effort was made to search for Rufous Scrub-bird territories outside the core study area; 10 extra 1-km transects at high altitude in the Gloucester Tops were surveyed. All of these surveys were in the same general area depicted in Figure 2—for example, two additional 1-km transects along the Careys Peak Track, a fourth 1-km transect along the Glowang Track, and some side tracks off Gloucester Tops Road were surveyed. There was a total of 14 such extra surveys over the 7 years. No Scrub-birds were detected during these additional surveys.

These findings suggest that the core habitat for Rufous Scrub-birds in the Gloucester Tops was confined to within the study area. However, each of the 10 additional transects was surveyed only once or twice. Additional surveys of those transects are needed in order to confirm that Scrub-birds are indeed absent. If the absence is confirmed, then a direction for further research would be to identify what factors (e.g. habitat differences, presence of predators) are involved. Such information could become important when developing future conservation strategies for Rufous Scrub-birds.

Conclusions

At the Gloucester Tops, 37 Rufous Scrub-bird territories in the sample area were identified as occupied in at least one breeding season. Twenty of those territories were classified as having long-term occupancy, involving the presence of a calling male in the breeding season for a period of at least three consecutive years during the study. Most of these long-term territories had confirmed records of Scrub-birds spanning five–seven seasons. Other territories appeared to be more transitory, occupied for 1–2 years but then with no further records or with a gap of some years before Scrub-birds were again recorded there. A period of 6–7 years was required for habitat suitable for Scrub-birds to re-establish after a major fire.

In both 2012 and 2013, abnormally dry conditions occurred in the Gloucester Tops in August–November immediately before and during the Scrub-bird breeding season. In both of these years, there was a decreased level of detection of Scrub-birds. Conversely, conditions apparently were very favourable in 2010 and to a lesser extent 2011, leading to an above-average detection of Scrub-birds. The reasons for this are unknown.

Usually, Rufous Scrub-bird territories in the study area were separated by distances ≥300 m, and in many cases there was >400 m between centres of territories. Four transects exhibited clustering, each having at least one territory situated within 250 m of the centre of another territory. In all four cases, the situation appeared not to be sustainable, with one of the territories occupied for only a limited period. Rufous Scrub-bird territory densities in the Gloucester Tops survey area were in the range 3.3–4.0 territories km^{-2}, similar to Ferrier's 1981 baseline levels (Ferrier 1984, 1985), which suggests that there has been limited change in status over a 35-year period, at least in core habitat. Thus, although monitoring of the subpopulation status will continue, the focus for future studies will be to investigate the behaviour of individual Scrub-birds in their territories, in the hope that such findings might help to optimise habitat-management strategies.

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Note added in proof: Based on several visits to the site in the 2017 breeding season, the 2016 Rufous Scrub-bird territory in the re-burnt area was no longer occupied.