Rufous Scrub-bird population trend in the Gloucester Tops: results from 2010-2019 monitoring program

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Two measures of the status of the Rufous Scrub-bird *Atrichornis rufescens* in the Gloucester Tops are proposed: the territory density in the area surveyed, and the number of new territories found. Territory density is independent of the amount of survey effort. The number of new territories potentially can be scaled in relation to survey effort. As the Rufous Scrub-bird surveys rely upon the availability and enthusiasm of volunteers, it is important to have status indices that are not affected by the amount of survey effort able to be achieved in any particular year.

In ten years of surveys in an area of core habitat for the Rufous Scrub-bird in the NSW Gloucester Tops, the territory density has fallen from 5.3 territories km^{-2} to 2.3 territories km^{-2}. The linear trend is a 5.5% decrease in territory density each year. The loss of territories seems to be primarily associated with dry conditions in what is assumed to be the breeding season. Wild fires were also a factor.

Establishment of new male Rufous Scrub-bird territories seems to be linked with wet conditions occurring in the breeding season two years prior, with also the need for favourable conditions in the intervening period.

INTRODUCTION

The ground-dwelling, poorly flying 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 *Biodiversity Conservation Act 2016*. The scrub-bird's very weak flight capability limits its dispersal potential and is an important contributing factor to its status as a threatened species.

There are several isolated populations in NSW and southern Queensland including a population of the southern sub-species *ferrieri* in the Barrington Tops National Park near Gloucester NSW (Stuart & Newman 2018). Every spring since 2010, a team of volunteers has monitored Rufous Scrub-bird territories in an area of known core habitat in that National Park (see **Figure 1**). The survey methodology involves teams walking along 1-km transects within a *c*. 5,000 ha section of the Gloucester Tops (approximately at 32.1º S, 151.6º E). The positions of all calling male birds are noted, and the regularly occupied sites are classified as territories (Stuart & Newman 2018). These more correctly would be termed "advertised territories". If a Rufous Scrub-bird is not heard calling from a known territory, there is no way (currently) of distinguishing whether the bird is absent or whether it is not calling.

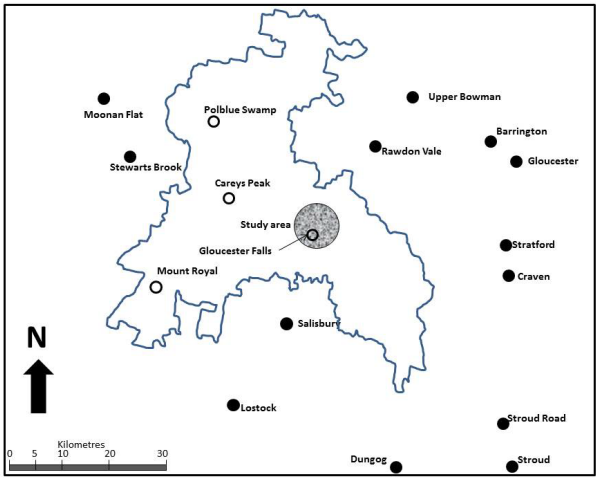

Figure 1. Barrington Tops National Park; the shaded area is where the annual spring surveys for Rufous Scrub-bird territories are carried out. (Figure reproduced from Stuart & Newman 2018).

Results from surveys in earlier years have been presented elsewhere (Newman *et al*. 2014; Stuart & Newman 2018). In this note I provide an update of recent results and an overall perspective of the 2010-2019 findings, including population trends

and the consequences of wet or dry weather conditions during the breeding season. I propose two indicators for assessing the status of a Rufous Scrub-bird population: the territory density and the number of new territories found each year. The concept of Rufous Scrub-bird population territory density is not new and has been discussed elsewhere (Ferrier 1984; Newman *et al*. 2014; Stuart & Newman 2018). Its potential as the key indicator of the status of the Gloucester Tops Rufous Scrub-bird population is because it is an index that is independent of the amount of survey effort undertaken in any given year. The territory density index potentially can also be applied to other Rufous Scrub-bird populations if they are monitored systematically.

In 2019-2020, wild fires destroyed large areas of Rufous Scrub-bird habitat in NSW and Queensland (BirdLife Australia unpublished). Fortunately, any fires in the Barrington Tops National Park were minor and the core Rufous Scrub-bird habitat in the Gloucester Tops was unaffected by fire in 2019-2020.

METHODS (Annual comparisons)

The amount of survey effort in the Gloucester Tops has varied from year to year (e.g. see Stuart & Newman 2018), mainly caused by resource constraints. When there are more volunteers, more transects can be surveyed and also the same transects can be surveyed more than once. In 2010-2014, every 1-km transect was surveyed at least twice. Since 2015, only a subset of eleven 1-km transects have been surveyed twice (or more) annually whilst in 2017, when there were problems with access to the study area, those eleven transects were only surveyed once.

The probability of detecting a Rufous Scrub-bird at its territory in the Gloucester Tops in September and October whilst walking along a transect that passes by the bird's territory is 70-80% when weather conditions are favourable (Ferrier 1984, pp. 77-78). Thus, after two passes along a transect, there is 91-96% probability that the scrub-bird will be detected if it is present.

The varying survey effort complicates attempts at annual comparisons. It is not valid to compare the number of territories detected each year, because some years have involved almost twice as much habitat being surveyed. Nor is it valid to compare the annual Reporting Rates (RR, where RR is the ratio of the number 1-km transects with scrub-bird records and the number of 1-km transects surveyed). That is because the number of scrub-bird territories within many of the individual 1-km transects has varied from year to year (Stuart & Newman 2018). Other sampling biases can also affect RRs, for example if a transect with a readily detected scrub-bird (i.e. a reliable singer) is visited more frequently or less frequently in a particular year's surveys.

A more valid annual comparison would seem to be the density of territories. The territory density concept is not new, for example territory density has been analysed in several prior studies (Ferrier 1984; Newman *et al*. 2014; Stuart & Newman 2018). My reason for suggesting it as a key indicator is that territory density should be independent of survey effort, assuming that all the surveys were in areas of equivalent potential habitat. That assumption seems reasonable, since all transects are in an area of core habitat (Stuart & Newman 2018). In this note I present the annual density of Rufous Scrub-bird territories in the Gloucester Tops survey area. I have assumed that each 1-km transect samples 30 ha of scrub-bird habitat. The basis for that assumption is that calling male Rufous Scrub-birds can be heard from a distance of *c*. 150 m under favourable conditions (Ferrier 1984). The Gloucester Tops surveys are only conducted in favourable conditions, and thus each transect samples an area 300 m wide and 1 km long.

Another measure I have examined is the number of new territories found each year. Studies in the Gloucester Tops and in New England National Park (Stuart & Newman 2018; Andren 2016) have shown that there is a mixture of long-term occupied territories and territories occupied for shorter time frames (of 1-3 years). The latter are assumed to be the territories of young male birds seeking to acquire breeding habitat. Therefore, the number of new territories found each year can be used as a measure of the health of the overall scrub-bird population, particularly if considered in relation to that year's overall survey effort.

It may be the case sometimes that a young male scrub-bird replaces or displaces an older male at a long-occupied territory. That outcome would be another indicator of the health of the overall population. However, at present we have no way to identify individual scrub-birds and hence to know if such an event has happened.

Rainfall

It has previously been suggested that Rufous Scrub-bird calling activity in the Gloucester Tops is related to weather conditions, with male birds ceasing to advertise territories (or perhaps leaving their territories) when conditions in spring were abnormally dry (Newman *et al*. 2014; Stuart & Newman 2018). Those previous inferences were based on awareness of the general rainfall patterns in the Hunter Region plus personal observations of ground conditions in the Gloucester Tops. However, it is now possible to look more closely at this, as I have discovered that there is a weather station at Careys Peak approximately 15 km from the study area. The weather station at Careys Peak is at *c.* 300 m higher altitude than the study area (Bureau of Meteorology (BOM) weather station 61413; location 32.05º S, 151.47º E, altitude 1430 m).

Rainfall at Careys Peak will be indicative of rainfall in the study area. Heavy rainfall events at Careys Peak probably were widespread, with comparable downfalls occurring in the study area. Lighter rainfall at Careys Peak may not necessarily have always been mirrored in the study area which is *c.* 15 km away. However, it seems reasonable to assume that the Gloucester Tops study area would have experienced a similar rainfall pattern to Careys Peak over the medium term (e.g. monthly).

Annual and monthly rainfall data for the Careys Peak weather station are available from the BOM website and are presented in **Table 1**. There are data from May 2009 onwards but over 2009-2011 there are several gaps in the monthly records. However, since July 2011 there are rainfall records for every day. **Table 1** shows the annual rainfall since 2012 and the amount of rain that fell in the period August to October each year for 2011-2019. The August to October period encompasses what is believed to be the breeding season for Rufous Scrub-birds in the Gloucester Tops plus the immediate lead-up to it. The calling activity of male scrub-birds increases from mid-September, remaining at a high level of activity until late January (Stuart & O'Leary 2019; Stuart 2019a). The Noisy Scrub-bird *A. clamosus* has an increased level of calling activity commencing in the lead-up to its winter breeding season (Berryman 2007); by analogy September-October is assumed to be the Rufous Scrub-bird's breeding season in the Gloucester Tops. It should be noted that there are no confirmed breeding records for Rufous Scrub-bird in the Gloucester Tops. However, two young birds were seen together in January 2019 (M. Kearns pers. comm.), which supports the assumption that breeding activities commence in spring.

Table 1. Annual rainfall recorded at the Careys Peak weather station and for the period August-October each year.

Year	Annual rainfall (mm)	Aug-Oct rainfall (mm)
2011	-	509
2012	2084	159
2013	2268	124
2014	1988	566
2015	2428	498
2016	2160	556
2017	2122	195
2018	2683	650
2019	1239	387

To find some information about the rainfall in 2009 and 2010 I used data from the Upper Allyn weather station (BOM station 61290). Although only at 315 m altitude it is the closest weather station for which I could find relevant data. For August to October 2009 and 2010 respectively, the Upper Allyn station recorded 215 mm and 294 mm of rain compared with 243 mm for the corresponding period in 2011. Therefore, in the Gloucester Tops study area, the amount of rain received in 2009 and 2010 probably was similar to the 509 mm received there in 2011 i.e. there were wet spring conditions in the Gloucester Tops in 2009 and 2010.

RESULTS

Table 2 shows, for each year, the number of kilometres surveyed (i.e. the number of 1-km transects), the number of Rufous Scrub-bird territories confirmed to be occupied, the territory density (as territories km^{-2}) and the number of new territories identified.

In 2010-2012, 20 km of transects were surveyed each spring, and 21 km of transects in 2013-2014 after the location of one of Ferrier's former survey locations was re-discovered (Stuart & Newman 2018). Only 11 km of transects were surveyed in 2015-2017. In 2018 and 2019 volunteer numbers were greater allowing additional survey effort: 20 km of transects in 2018 and 16 km in 2019.

Thirty-two Rufous Scrub-bird territories were identified in the 2010 and 2011 surveys. In the subsequent years, fewer territories have been located each year. When considered as density of territories, there were 5.3 territories km^{-2} in 2010 and 2011, and the density had decreased to 2.3 territories km^{-2} in 2019 (**Table 2**).

Two new territories were identified in 2011; there had not been any scrub-bird detected at either location in 2010. In 2013, two territories were found within a previously unsurveyed 1-km transect (Stuart & Newman 2018). For the purposes of this review, they have not been treated as new territories, since they may have been occupied for several years unbeknown to us.

In 2016, three new territories were identified. Two of those were completely new i.e. scrub-birds had never before been detected at either location in any of the 2010-2015 surveys. These territories were occupied for two and one breeding seasons respectively. The third "new" location for 2016 was near to where there was a territory occupied continuously in the 2010-2013 annual surveys. However, that territory appeared to be unoccupied (i.e. was unadvertised) in the 2014 and 2015 surveys and in many visits in other seasons of those two years (Stuart 2019b). Therefore, it seems reasonable to assume that a new male Rufous Scrub-bird claimed the old territory at some time in 2016. Further evidence to support that assumption is that the territory position was slightly relocated from the original position (Stuart 2019b). The

territory has been occupied continuously over 2016-2019.

Similarly, in 2018 a scrub-bird territory was identified close to a location where there had been a territory in 2010-2015 but which apparently was unoccupied in the 2016-2017 surveys (and in many other visits in those two years). Again, I have assumed that a new male Rufous Scrub-bird had occupied the territory (and which continued to be occupied in the 2019 surveys).

Table 2. Results from annual spring Rufous Scrub-bird surveys in the Gloucester Tops.

Year	No. of 1-km transects	No. of occupied territories	Territory density (terr. km^{-2})	No. of new territories
2010	20	32	5.3	NA*
2011	20	32	5.3	2
2012	20	22	3.7	0
2013	21	20	3.2	0#
2014	21	25	4.0	0
2015	11	12	3.6	0
2016	11	13	3.9	3
2017	11	9	2.7	0
2018	20	17	2.8	1
2019	16	11	2.3	0

**The first of the annual surveys; thus, all territories were "new".*
#Two territories were found in a previously unsurveyed 1-km transect.

A subset of survey transects

The variation in the number of transects surveyed over 2010-2019 potentially complicates the analysis of results. Therefore, it is helpful to also examine the results from a consistently monitored subset of transects. There are eleven 1-km transects which have been surveyed every spring in 2013-2019. **Table 3** shows the results for those eleven transects in those seven years. Twelve territories were occupied (i.e. advertised) in 2013 while in 2019 there were seven occupied territories. The territory density was 3.6 territories km^{-2} in 2013 and 2.1 territories km^{-2} in 2019. Three new territories were discovered in 2016 and one new territory in 2018. These are the same four new territories discussed above.

Table 3. Annual territory density and number of new territories in an eleven 1-km transect subset, for which every 1-km transect was surveyed annually over 2013-2019.

Year	No. of occupied territories	Territory density (terr. km^{-2})	No. of new territories
2013	12	3.6	0
2014	11	3.3	0
2015	12	3.6	0
2016	13	3.9	3
2017	9	2.7	0
2018	8	2.4	1
2019	7	2.1	0

DISCUSSION

Changes in territory density

The mean territory density for the ten-year study has been 3.7 territories km^{-2} (Standard Deviation 1.0 territories km^{-2}, Coefficient of Variation 27.5%). At face value, these statistical data might suggest natural variation within an overall stable population. However, in looking at the trend over time, there has been a substantial decline in Rufous Scrub-bird territory density in the study since the annual surveys began in 2010. The territory density was 5.3 territories km^{-2} in the first two years of surveys while in 2019 it was nearly 60% lower, at 2.3 territories km^{-2} (**Table 2**). A similar decline is apparent in the results for the subset of eleven consistently surveyed transects (**Table 3**), for which the territory density was 42% lower in 2019 than in 2013. Comparing the periods 2013-2019 in the **Tables 1** and **2**, the decreases are very similar. Hence the changes presented in **Table 2** cannot be an artefact of the varying annual survey effort.

The changes over 2010-2019 correspond to a linear trend of a 5.5% annual rate of decline (with R^2 0.75), presented graphically in **Figure 2** (using data from **Table 2**).

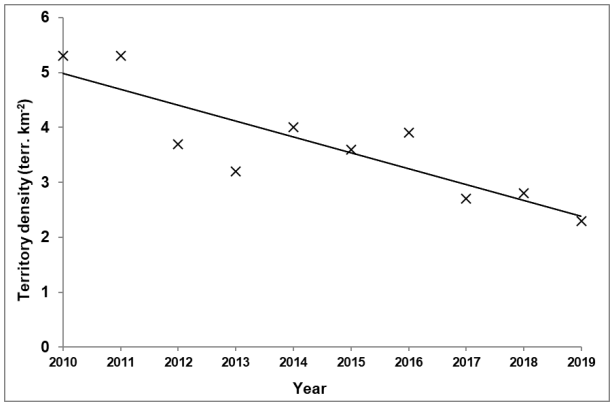

Figure 2. Annual territory densities in the Gloucester Tops survey area 2010-2019 and the linear trend.

The decline in territory density may be linked to two factors – wild fires and dry conditions. A fire in 2009 affected part of the study area. Although the burnt area was large, only one 1-km transect in the study area was affected; the final *c*. 700 m of it.

It was seven years before a new Rufous Scrub-bird territory was established in the previously burnt section of that particular transect (Stuart & Newman 2018). Unfortunately, the same area was burnt again in November 2016 as the result of another lightning strike. In the subsequent three sets of annual spring surveys, no scrub-birds have been detected in that part of the study area.
The 2009 fire might have contributed to the higher territory densities found in the 2010 and 2011 surveys, on the assumption that some scrub-birds were able to flee the fire and attempt to establish new territories in unburnt areas.

However, the consequences of dry conditions in spring seem clear. **Figure 3** shows the annual August-October rainfall received at the Careys Peak weather station and the territory density result for that year's surveys. The first two years of surveys received good amounts of spring rainfall and the Rufous Scrub-bird activity was high. In 2012 and 2013 the August to October conditions were dry (159 mm and 124 mm respectively) and the number of scrub-bird territories (analysed as territory density) decreased. In the following three wet springs, the territory density seemed stable and probably had increased slightly over the 2012-2013 situation, from 3.2 territories km^{-2} in the dry spring of 2013 rising to 4.0 territories km^{-2} in 2014 (**Table 2**). Conditions in 2017 again were dry, only 195 mm in the August to October period, and the territory density dropped to 2.7 territories km^{-2}. The density decreased even further in 2019, to 2.3 territories km^{-2} (**Table 2**). Superficially, 2019 had wetter August-October conditions, with 387 mm of rain. However, that included 183 mm falling in a single two-day period (18-19 September) i.e. the conditions for the overall period were quite dry. Also, the annual rainfall for 2019 was about half the normal amount (**Table 1**). The dry conditions prevailing all year will have limited the impact of any rain falling during the breeding season.

In Ferrier's Rufous Scrub-bird surveys in the Gloucester Tops in 1979-83, he found the territory density to be 3.3 territories km^{-2} on average (Ferrier 1984). That result is similar to the 2012-2016 territory density findings, which were in the range 3.2-4.0 territories km^{-2} (**Table 2**). We do not know the specific weather conditions in the Gloucester Tops at that time; however, all of eastern Australia was in drought in 1979-1982 (Wikipedia 2020) and so the conditions in the Gloucester Tops probably were relatively dry. Supporting that view, Ferrier presented monthly rainfall data for Chichester Dam, about 15 km south and at an altitude of 194 m. In most months

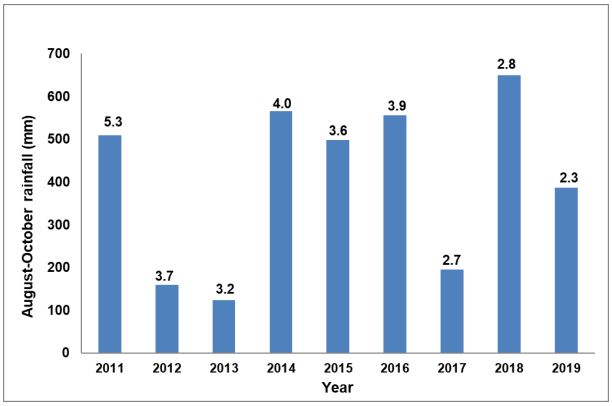

Figure 3. Annual August-October rainfall at the Careys Peak weather station and the territory density (as territories km^{-2}) found during that year's surveys (territory densities are labelled above that year's rainfall column).

during Ferrier's study the rainfall at Chichester Dam was below average and only seven months over 1979-1982 had above-average rainfall (Ferrier 1984, p. 29).

The changes in territory density over 2010-2019 may be part of a natural cycle, in which a stable population oscillates around a mean. The territory density in 2010 may have represented a short-term population peak driven by favourable weather conditions in 2009-2010 and an influx of mature adults displaced by fires external to the study area and 2019 a minimum driven by extreme rainfall conditions. Alternatively, the changes since 2010 might be a harbinger of serious problems for the Rufous Scrub-bird. Ten years probably is too short a time frame to be able to differentiate between those two scenarios. The need for an ongoing monitoring program is quite clear.

Establishing new territories

Two new territories were identified in 2011, both were within transects across the Gloucester River. This followed what likely were wet conditions in 2009 and 2010. No more new territories were found until three were identified in the 2016 surveys. That followed wet August to October conditions in 2014 and 2015 (**Table 1**). There was one new territory in the 2018 surveys. Although 2017 had dry spring conditions, 2016 was wetter in the supposed breeding season, with 556 mm of rain falling over August-October.

Although little is known for certain about Rufous Scrub-bird breeding biology, the males are thought to begin breeding at two years of age (Garnett *et al*. 2011, p. 281). That time frame for sexual

maturity matches with the pattern of new territories establishing after wet conditions occurring two years earlier. Thus, the new territories in 2011 followed wet conditions in 2009, those in 2016 align with wet conditions in 2014, and the new territory in 2018 was after wet August-October conditions in 2016.

Conditions also were wet in 2015 but there were no new territories identified in the 2017 surveys. However, 2017 had a dry August-October period and the conditions may not have been suitable for inexperienced young males to successfully maintain a territory.

Similar rainfall-linked population changes have been noted for the Grey Fantail *Rhipidura fuliginosa* at Green Wattle Creek although the situation there was more complex because of passage migrants as well as a resident population (Newman 2012). In the Green Wattle Creek case there was a one-year lag for population increases after above-average rainfall and for population decreases during dryer times. The Grey Fantail typically begins breeding when one year old (Higgins *et al*. 2006), whereas for the Rufous Scrub-bird it is two years.

CONCLUSIONS

Two indicators of Rufous Scrub-bird population status are proposed: the territory density obtained from annual surveys in the breeding season and the number of new territories found in those same surveys. Territory density is independent of the varying survey effort that is intrinsically linked with efforts by volunteers. The number of new territories found will be dependent upon the survey effort but potentially can be scaled in relation to it.

In the ten years of Rufous Scrub-bird surveys in an area of their core habitat in the Gloucester Tops, the territory density has fallen from 5.3 territories km^{-2} to 2.3 territories km^{-2}. The linear trend is a 5.5% decrease in territory density each year. Most of the overall decrease seems to be associated with the dry conditions which have prevailed in the supposed breeding season in many years since 2010. Also, wild fires have impacted some former areas inhabited by scrub-birds. Of concern is that these two processes are additive; dry conditions diminish the number of Rufous Scrub-bird territories, as do fires, and dry conditions increase the likelihood of fires occurring.

It is normal for bird populations to oscillate about a stable mean and it would be premature to conclude that the core habitat population of Rufous Scrub-bird is unstable. The first surveys in 2010 may have represented a short-term population peak driven by an influx of mature adults displaced by fires external to the study area and 2019 a minimum driven by extreme rainfall conditions. Consequently, monitoring of the Rufous Scrub-bird population in the Gloucester Tops needs to continue, in order to determine whether the present changes are part of the normal cycle of a stable population or an ongoing decline.

Recovery in territory density should be possible if weather conditions are favourable for long enough. It seems to require at least two years of favourable conditions before young male scrub-birds reach maturity and try to establish new territories. Several years of favourable conditions seemingly will be required before the scrub-bird territory densities could return to the levels found in 2010-2011.

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