Threatened birds on Dirk Hartog Island, 2017-18 report: population estimates

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Summary

Three threatened terrestrial bird subspecies are endemic to Dirk Hartog Island: subspecies of the Rufous Fieldwren, Southern Emu-wren and White-winged Fairy-wren (black and white subspecies). The widespread Variegated Fairy-wren is also present on the island. For each species, we set out to determine habitat usage, estimate population size, provide a preliminary indication of annual variability in population size, model variation in density across the island, and make recommendations for future monitoring.

We surveyed for species occurrence in May and September 2013, and September 2014, and gathered abundance data in August 2015 and September 2016. The fieldwren is common and widespread on the island, the two fairy-wrens are moderately widely distributed, and the emu-wren, while moderately widely distributed, is more common in the north of the island than in the south. Modelling of distance-sampling data collected in 2015 and 2016 has provided preliminary population estimates of 17000-37000 emu-wrens, 15000-24000 White-winged Fairy-wrens, 34000-39000 Variegated Fairy-wrens and 12000-20000 fieldwrens. All four species were more abundant in 2015 than in 2016. In each year, the Variegated Fairy-wren was the most abundant, followed by the Southern Emu-wren, White-winged Fairy-wren and Rufous Fieldwren. For the least common species, this equates to about one pair for every six hectares of suitable habitat in 2016. Density surface modelling has been used to provide a visual tool to estimate density of each of the study species across the island.

Distance sampling provides robust estimates of population size and density. However, under current levels of resource availability, it is not likely to be a practical alternative for routine monitoring. A simpler occupancy approach would be easier to implement for routine monitoring, but this will only provide a very coarse estimate of population trend. For

management decisions to be made with confidence, the threatened species should be monitored in more detail (using distance sampling) at five year intervals.

Introduction

There are three bird subspecies endemic to Dirk Hartog Island: the Dirk Hartog Island Black-and-White Fairy-wren *Malurus leucopterus leucopterus* (a subspecies of the widespread White-winged Fairy-wren), Dirk Hartog Island Southern Emu-wren *Stipiturus malachurus hartogi* and Dirk Hartog Island Rufous Fieldwren *Calamanthus campestris hartogi* (Appendix 1). In addition, the Western Grasswren *Amytornis textilis textilis* once also occurred on Dirk Hartog Island. Further details on the individual taxa are presented in Johnstone and Storr (2004), Burbidge (2013) and Burbidge *et al*. (2013, 2015, 2016).

Dirk Hartog Island is the largest island in Western Australia, with an area of about 59 000 hectares. Europeans first encountered the island in 1616, beginning a long maritime and settlement history. Permanent occupation began in 1869. In earlier times, there were up to 26 000 sheep on the island, but by the time the island became a national park in 2009, there were 5000 - 6000 sheep and more than 3000 goats present, as well as an unknown but significant number of feral cats (Abbott 2007; Gillen *et al*. 2011). Under a comprehensive ecological reconstruction project underway on the island, sheep, goats and feral cats have been removed, and locally extinct native species will be re-introduced over the next decade (Gillen *et al*. 2011; Thomas *et al*. 2016).

The current study was initiated to determine distribution and population levels of the threatened bird taxa following the long period of grazing by domestic animals and presumed long-term predation by feral cats, to provide a basis for future management action and to monitor the status of the bird taxa. The first aim was to establish the distribution of the threatened bird species on the island, and to determine their habitat preferences. The second aim was to develop a monitoring framework that can be used to assess population trends in the threatened birds following the removal of cats and other threats from the island.

Distance sampling (Buckland *et al*. 2001) is a widely used group of methods for estimating abundance and/or density of biological populations. Distance sampling has been used extensively in both terrestrial and marine ecology (e.g. Katsanevakis 2007; Watson *et al*. 2012). Distance sampling methods utilise points or line transects. With line transects, a standardized survey is conducted along a series of lines searching for the objects (animals) of interest. For each animal detected, the distance from the line or point is recorded. A detection function is fitted from the set of recorded distances, which is used to estimate the proportion of animals missed by the survey and hence estimate abundance. When the detection of individuals is difficult (such as in cryptic species like emu-wrens), a distance sampling method is typically more efficient than simple strip transect sampling. This is because densities are corrected with the use of the detection function and the sample size is larger for the same amount of effort as all detected individuals may be recorded regardless of how far they are from the line.

Density surface modelling integrates modelling of sampling data (density estimates) with spatial modelling in a Geographic Information System (GIS). This permits modelling of the relationship of animal density to spatial variables, reflecting various factors like topography or habitat (Hedley *et al*. 2004), allowing heterogeneity in the spatial distribution of the species of interest to be modelled from standard line transect data.

This report provides a summary of modelling of the occurrence and abundance data for each of the threatened bird species on Dirk Hartog Island, and makes recommendations for future monitoring.

Methods

Field sampling

In August 2015 we established 28 transects for use in distance sampling (Buckland *et al*. 2001) to provide estimates of population size. In September 2016 an extra six (more remote) transects were established to provide better spatial coverage of the island. We used the same approach that is used for monitoring the other subspecies of black and white fairy-wren, *M. leucopterus edouardi*, on Barrow Island (Biota Environmental Sciences 2010, 2013; Chevron Australia 2015). Use of the same approach is expected to provide robust, repeatable measures of density, together with the basis for a meaningful comparison with Barrow Island and Hermite Island monitoring data for the black and white fairy-wrens.

Sampling was carried out during 5th-18th August 2015 and 6th-18th September 2016. Field personnel in 2015 were Allan Burbidge (DBCA), Stewart Ford and Jacinta King (volunteers), and in 2016 Allan Burbidge and Mark Blythman (DBCA), Stewart Ford and Jacinta King (volunteers). Sampling in August 2015 followed a wetter than normal winter (Figure 1) and heavy rain fell at the beginning of the field sampling. The 2016 sampling followed a slightly drier than normal period. Maximum temperatures at this time of year (August-September) are in the low twenties (Figure 1).

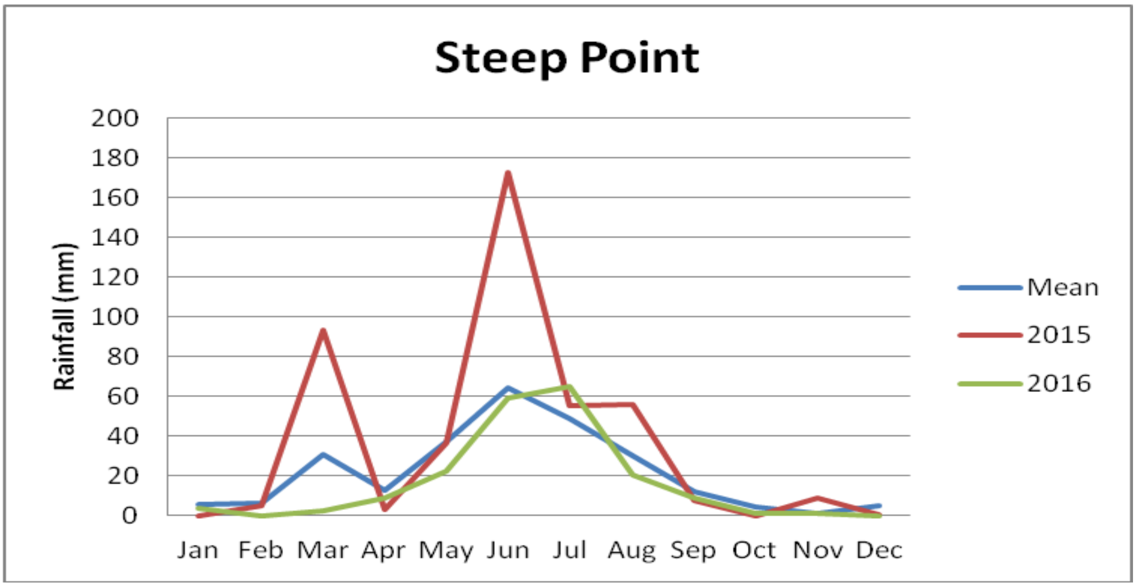

Figure 1(a). Monthly rainfall for the nearest rainfall station (Steep Point, just south of the southern tip of Dirk Hartog Island). Blue = long-term mean, red = 2015 and green = 2016 rainfall. (Data from Bureau of Meteorology, http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=139&p_display_type=dataFile&p_startYear=&p_c=&p_stn_num=006102)

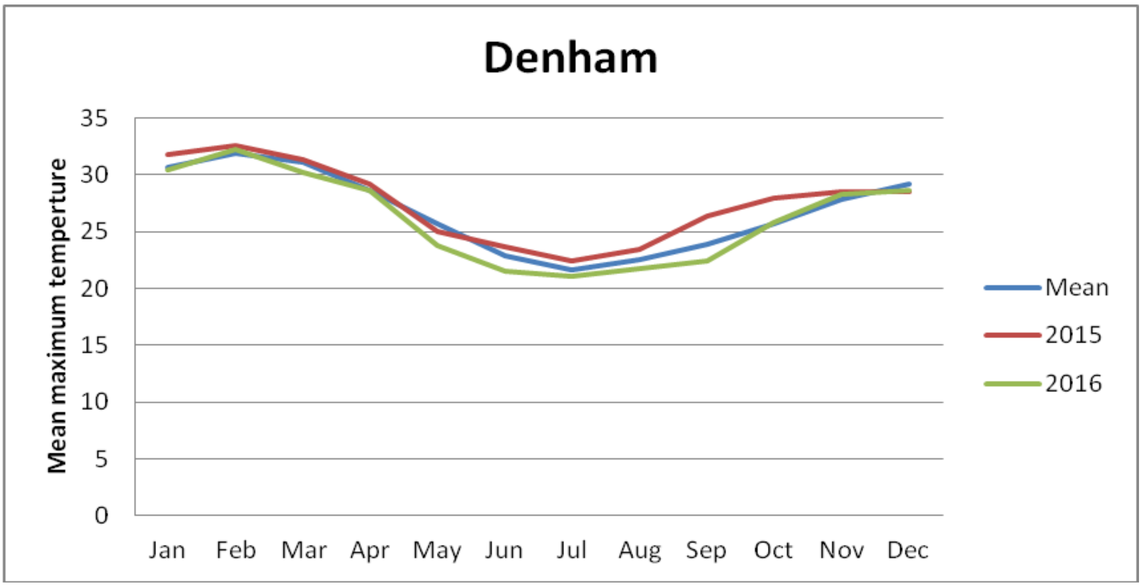

Figure 1(b). Monthly mean maximum temperature for the nearest temperature recording station (Denham, about 50 km east of Dirk Hartog Island). Blue = long-term mean, red = 2015 and green = 2016 rainfall. (Data from Bureau of Meteorology, http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=36&p_display_type=dataFile&p_startYear=&p_c=&p_stn_num=006044)

A 5 x 5 km east-west/north-south grid was placed over the island to aid in the positioning of transects. Transects were arranged in an east-west fashion and spatially distributed 5 km apart (north-south) across the island (Figure 2). Each transect was two kilometres long, with the exception of a few that had to be truncated because of the width of the island. Access on the island is limited and several transects commenced at an access point rather than being truly randomly placed.

In 2015, 28 transects totalling 55.4 km were walked, while in 2016 the number of transects was increased to 31 transects totalling 62.9 km. Extra transects were added to improve coverage of the island, thereby minimising the probability of missing any significant geographic or vegetation features, and hence improving the robustness of total population estimates and models

Counts of Rufous Fieldwren, Southern Emu-wren, White-winged Fairy-wren and Variegated Fairy-wren were undertaken. Transects were walked by either one or two observers familiar with distance sampling and the four bird species of interest. Most were conducted in the few hours immediately after sunrise when bird activity was greatest. However, on some mornings, strong winds or rainfall precluded field activities, and due to time constrains some transects were therefore walked in the late afternoon if the weather had cleared. Wind speed at the commencement of each transect was recorded, as it was whenever a target species was observed. When a target species was observed, the location was recorded using GPS, and the size of the group and the initial cue for the observation (i.e. sighting or call type) were noted. Each person was responsible for detecting the target species.

Density and abundance estimates

Perpendicular distances were calculated using GIS to determine the closest distance to the transect based on each group's (including single birds) GPS location. Line transect data were analysed using conventional distance sampling (CDS), multiple covariates distance sampling (MCDS) and/or mark-recapture distance sampling (MRDS) modules of program Distance 7 Release 1 (Thomas *et al*. 2010) as well as the **mrds** (Laake *et al*. 2013) and **Distance** (Miller 2013) packages in **R** statistical software (R Core Team 2013). Probability density functions (PDFs) were modelled based on the histograms of perpendicular distance measurements to groups of birds. A histogram of the perpendicular distance from the transect to the bird or group can indicate whether evasive movement of animals prior to detection by the observer was occurring, evidenced by lower numbers of records close to the transect which then increase with distance from it (Buckland *et al*. 2001).

Histograms were right-truncated where necessary to achieve better model fit, guided by the distance at which detection probability was 0.15 as recommended by Buckland *et al*. (2001). Akaike's Informative Criterion (AIC) is a quantitative method of model selection and enables selection of the optimal model (Buckland *et al*. 2001). The fit of candidate models was compared using AIC, a visual inspection of their fit, Kolmogorov-Smirnov and cosine-weighted Cramér-Von Mises tests (Buckland *et al*. 2004).

The selected models were used to estimate the following parameters:

- the encounter rate (n/L) (where n=number of observed clusters (groups of birds) and L the total length of the transect;
- an estimate of density of clusters (DS);
- an estimate of density of animals (D); and
- an estimate of abundance (N).

To test whether there was a greater tendency to detect larger clusters (relative to smaller ones) further away from the transect (i.e. a size bias), the log of cluster size against detection probability was regressed to determine whether the slope was significantly different from zero at $\alpha = 0.15$, as recommended by Buckland et al. (2001). Where the slope was not significantly different, the mean of cluster size was used rather than the size-bias adjusted cluster size.

Once a model was selected, the MCDS module was used for the analysis and the effect of various covariates (i.e. observer and/or cue) on model fit was assessed. Size-bias correction of cluster size was applied when the slope of the regression of cluster size differed from zero at a significance level $\alpha = 0.15$. Density was estimated for the whole island.

Density surface modelling

In addition to the design-based methods listed above, model based methods were used to model the density of each species as a function of spatially indexed environmental covariates (Thomas *et al*. 2010). Analysis was undertaken in **R** (v. 3.3.2) using the **mrds** and **dsm** packages.

In this method, segment counts are modelled as a function of covariates, in this case a number of layers produced by an earlier investigation of each species' distribution on Dirk Hartog Island (Ball *et al*. 2015). These were: NDVI (measure of greenness and extent), vegetation cover (measure of vegetation cover expressed as a percentage), ridges (measure of local ridges and valleys), altitude and logistic models of presence/absence based on field collected data (*rf_logreg*, *emu_logreg*, *bw_logreg* and *vr_logreg*) (Ball *et al*. 2015). Because the logistic models were produced from NDVI and vegetation cover layers, these were not included in the analysis together to avoid autocorrelation.

In almost all analyses, inclusion of the species suitability maps were informative in the density surface models and were included in the density surface model. Models selection for each species' DSM in each year proceeded based on p-values associated with each covariate, the percentage deviance explained and AIC. Each analysis included geographic information (latitude, longitude) with some also including smooths of NDVI, percentage cover and/or the species suitability layer (**_logreg* listed previously). A general formula applicable to most models was:

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n ~ s(x,y)+s('covariate')
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The tweedie distribution was applied in all instances and models were fit using the `gam` engine.

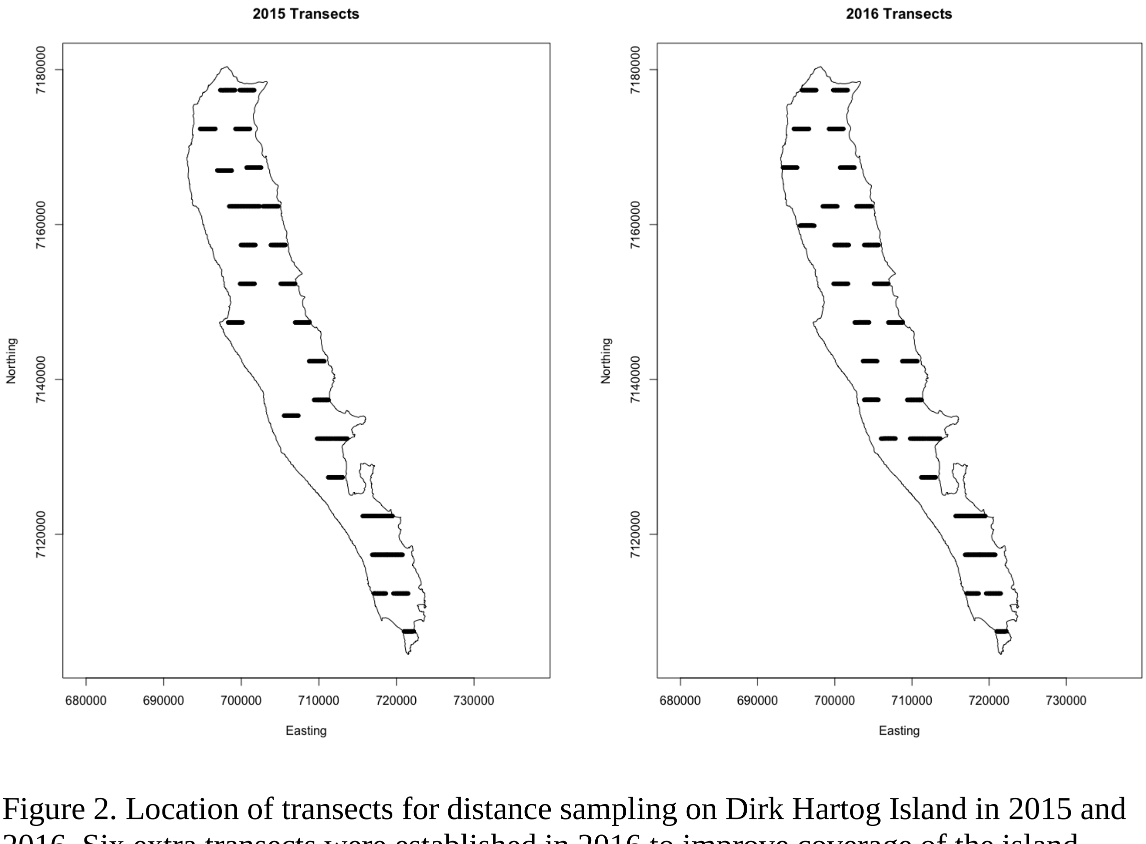


Figure 2. Location of transects for distance sampling on Dirk Hartog Island in 2015 and 2016. Six extra transects were established in 2016 to improve coverage of the island.

Results

Population Estimates

Analysis of the 2015 and 2016 distance data indicated population sizes of approximately 12 000-40 000 birds (Table 1), depending on the species and year. All four species were more abundant in 2015 than in 2016, although the differences for the fairy-wrens are not statistically significant (Figure 3). Average group size was also greater in 2015, except for the Rufous Fieldwren. The number of groups per square kilometre was greater for the Southern Emu-wren and Rufous Fieldwren in 2015, but not significantly different between years for the fairy-wrens (Figure 4).

Species	Groups per square kilometre		Average group size		Island abundance	
	2015	**2016**	**2015**	**2016**	**2015**	**2016**
Southern Emu-wren	32.1 ± 7.4	15.3 ± 4.5	1.82 ± 0.07	1.79 ± 0.14	37,153 ± 8,664	17,122 ± 5,029
White-winged Fairy-wren	12.4 ± 2.8	9.54 ± 2.4	2.97 ± 0.16	2.56 ± 0.13	24,330 ± 5,915	15,297 ± 3,862
Variegated Fairy-wren	18.8 ± 3.7	19.5 ± 2.7	3.21 ± 0.17	2.76 ± 0.11	38,527 ± 7,770	33,845 ± 5,096
Rufous Fieldwren	29.4 ± 4.0	16.1 ± 4.0	1.07 ± 0.02	1.19 ± 0.09	20,136 ± 2,767	12,016 ± 3,232

Table 1. Estimates of the abundance of threatened terrestrial birds on Dirk Hartog Island, based on distance sampling using 28 transects in August 2015 and 33 in September 2016.

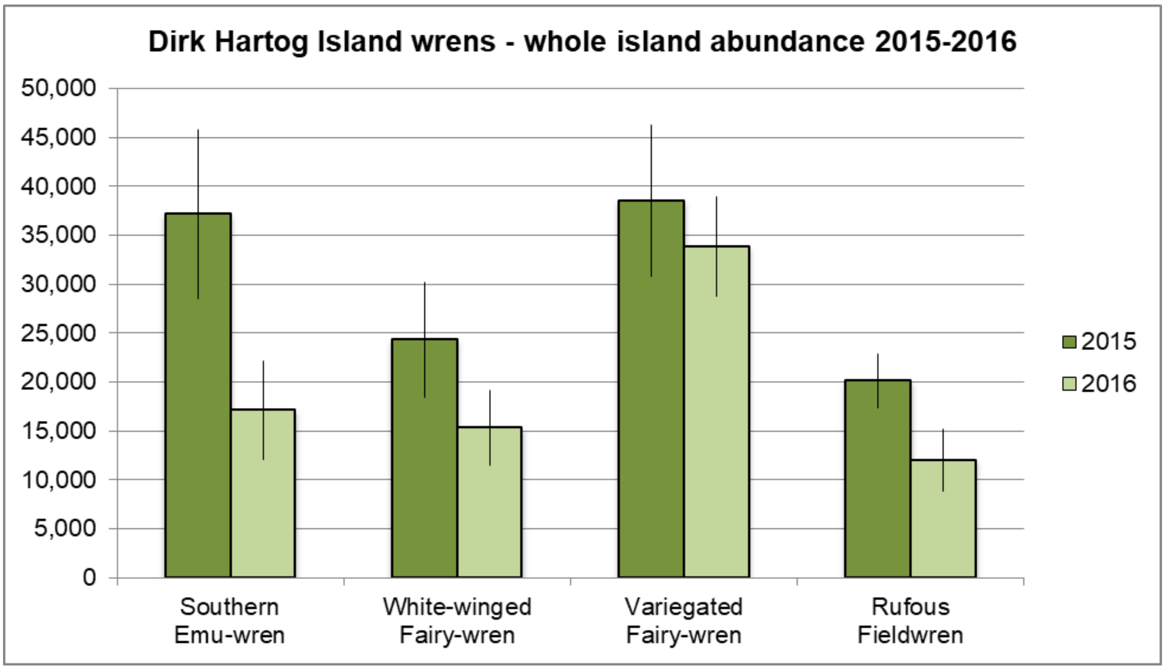


Figure 3. Total populations of four passerine bird species on Dirk Hartog Island, 2015 and 2016, as estimated by distance sampling.

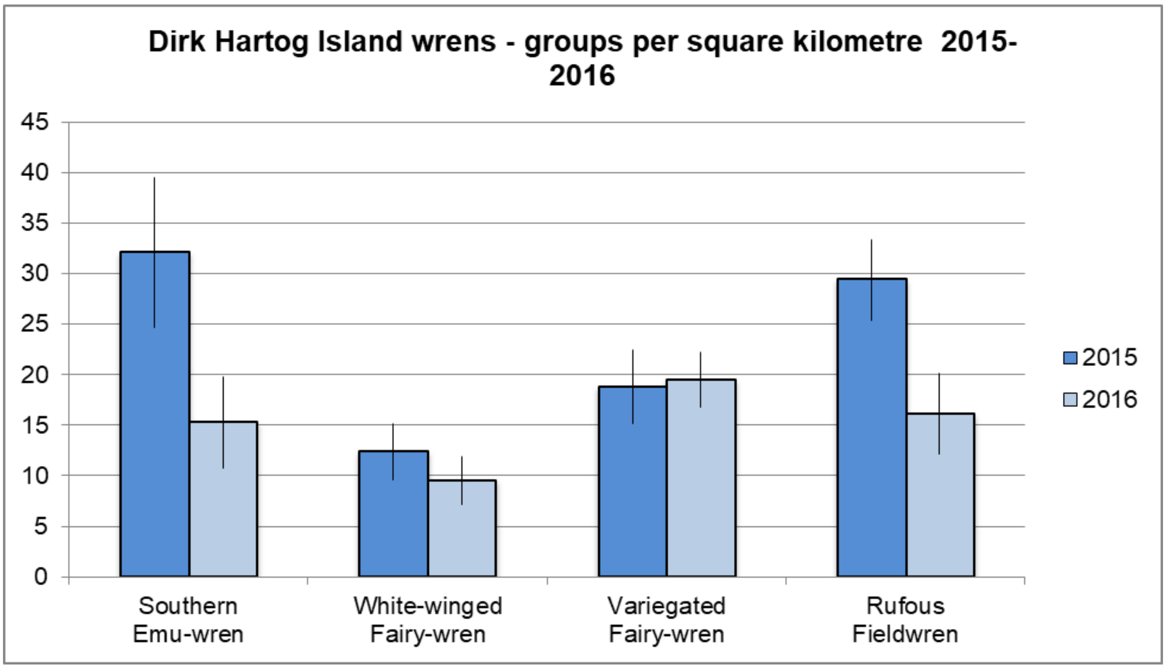


Figure 4. Density of groups of four passerine bird species on Dirk Hartog Island, 2015 and 2016, as estimated through distance sampling.

Within the 2016 data, the detection histograms (Figure 5) all indicated that the data were suitable for analysis, although it appears that we may have missed some Southern Emu-wrens and/or pushed some away from the transect before detecting them. Further analysis is required before we can fully interpret these data.

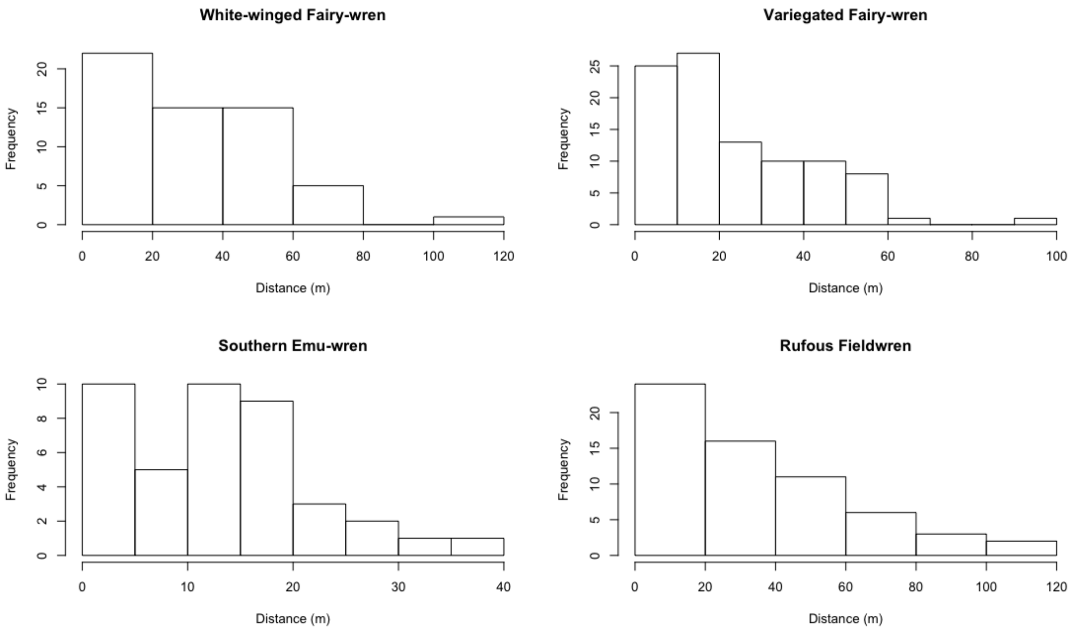


Figure 5: Detection characteristics for four target species, based on 2016 sampling data.

While the population estimates for each species dropped from 2015 to 2016, the group density also dropped except for Variegated Fairy-wrens. Similarly, the Variegated Fairy-wren was the only species to be seen on more transects in 2016 than 2015 (Table 2).

	Abundance (Individuals)			Group Density (Groups/km^2)			No of transects		
	2015	2016	% Change	2015	2016	% Change	2015	2016	% Change
Southern Emu-wren	37,153	17,122	-54	32.1	15.3	-52	22	18	-24
White-winged Fairy-wren	24,330	15,297	-37	12.4	9.54	-23	22	19	-20
Variegated Fairy-wren	38,527	33,845	-12	18.8	19.5	+4	23	27	+10
Rufous Fieldwren	20,136	12,016	-40	29.4	16.1	-45	28	23	-23

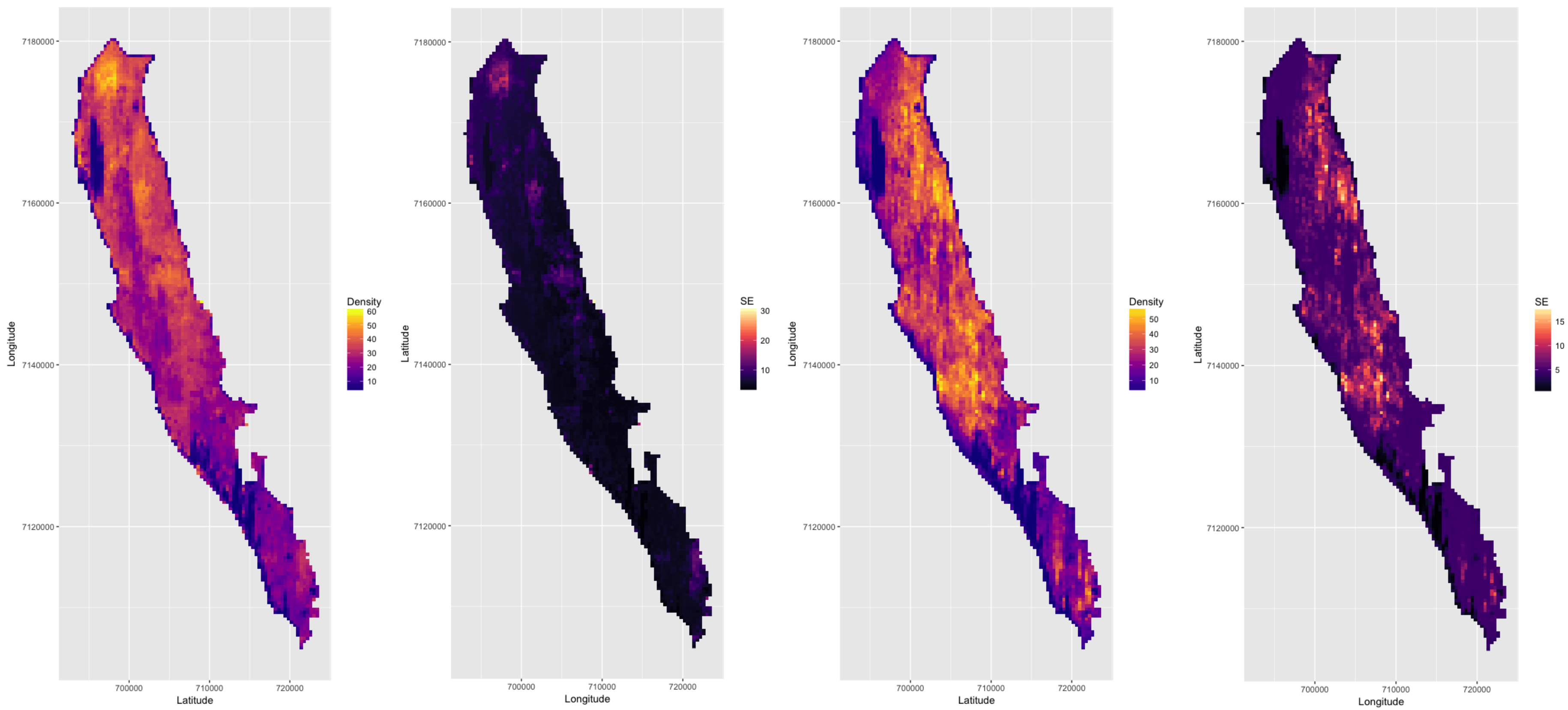
Table 2. Changes in abundance, group density, and presence on transects, for bird species on Dirk Hartog Island, 2015-16.

Density Surface Models

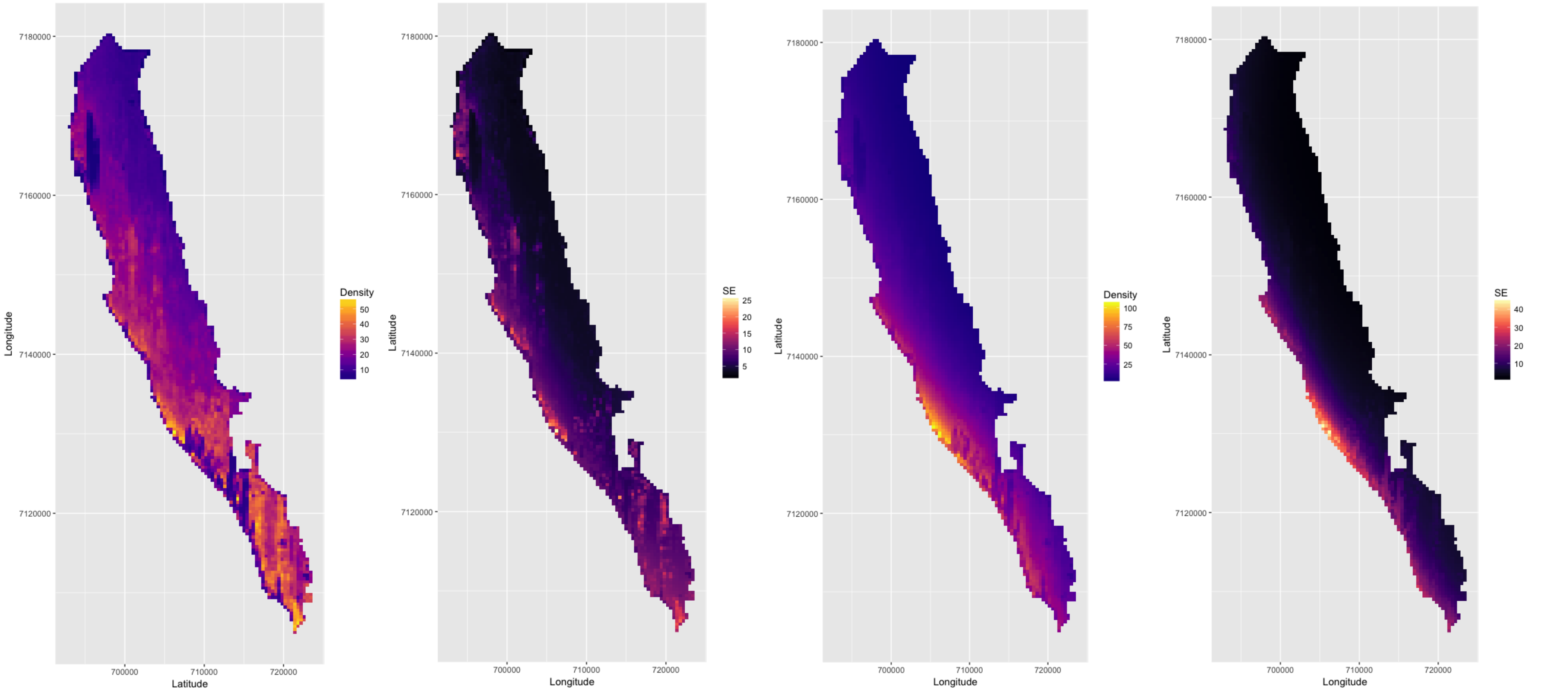
Overall patterns in the abundance of each species were similar in the two years 2015 and 2016 (Figure 6), although there were some differences in areas of peak abundance between years. In particular, the DSM for the Rufous Fieldwren was relatively uniform in 2015, when the species was conspicuous across most of the island.

Figure 6 (below). Density surface models (DSMs) for (a) Southern Emu-wren, (b) black and white White-winged Fairy-wren, (c) Variegated Fairy-wren and (d) Rufous Fieldwren on Dirk Hartog Island, based on 2015 and 2016 transect data. Each set of four maps represents 2015 density surface, 2015 standard error, 2016 density surface and 2016 standard errors. Density is displayed as number of individuals/km^2.

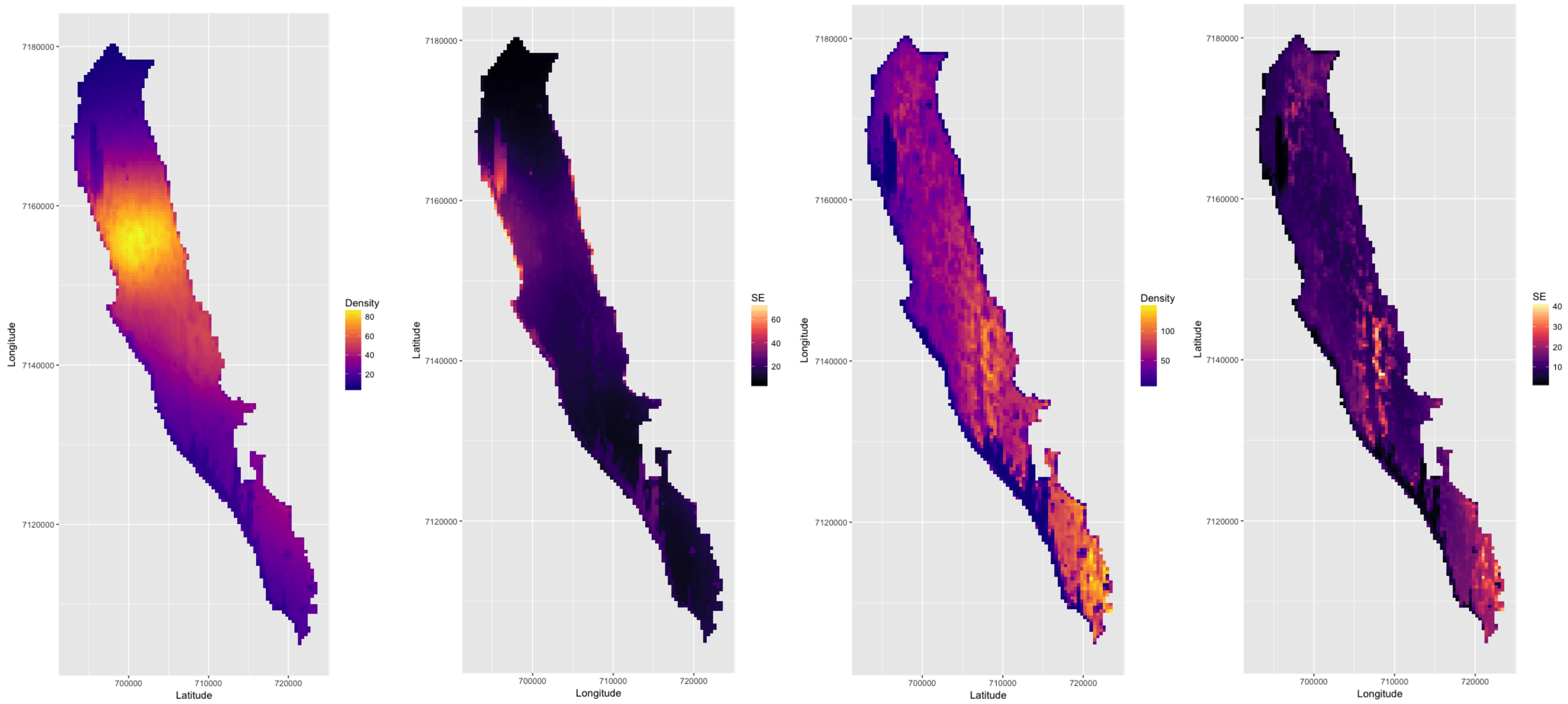
(a) Southern Emu-wren, 2015 (density, standard error) and 2016 (density, standard error)



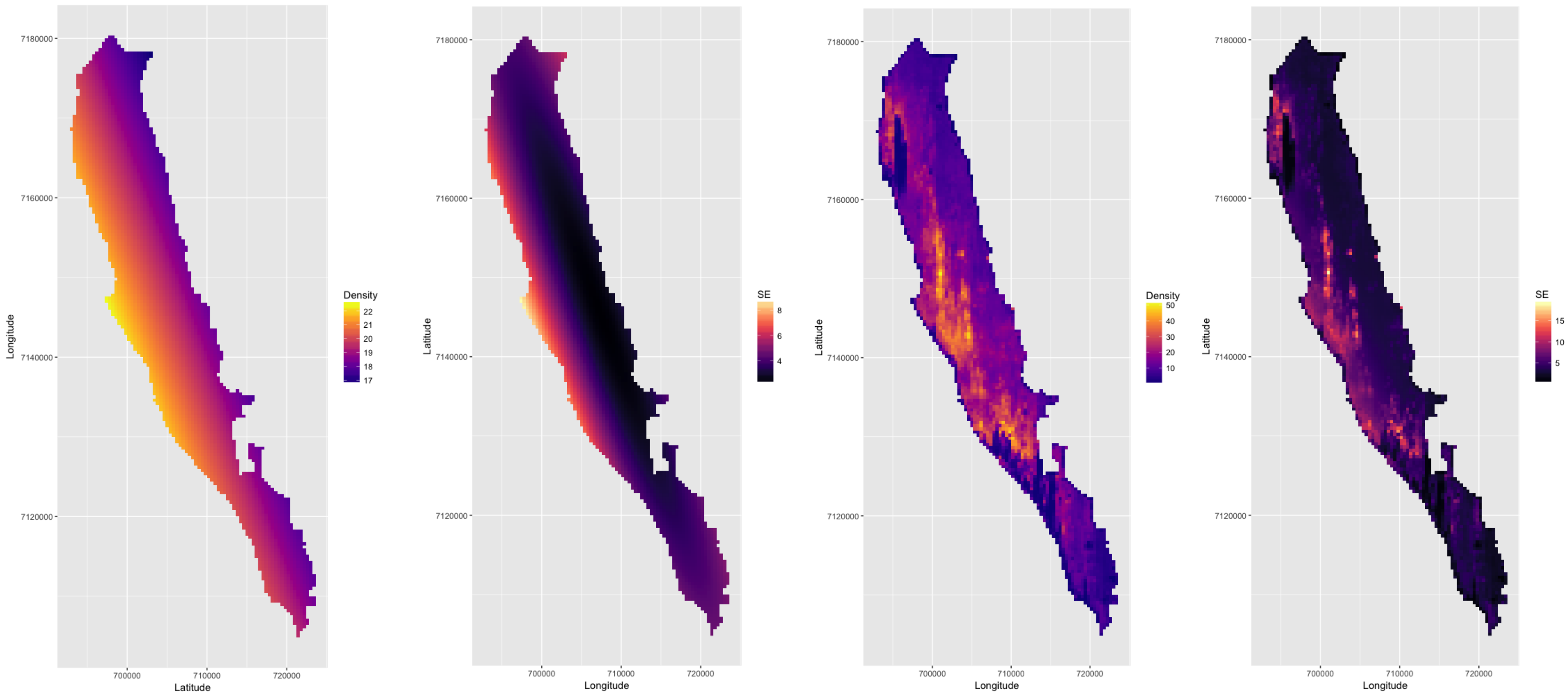
(b) White-winged Fairy-wren, 2015 (density, standard error) and 2016 (density, standard error)



(c) Variegated Fairy-wren, 2015 (density, standard error) and 2016 (density, standard error)



(d) Rufous Fieldwren, 2015 (density, standard error) and 2016 (density, standard error)



Discussion

All four study species were noticeably less abundant in 2016 compared with 2015, as demonstrated by the total abundance figures and in the DSMs. Two years of data are not enough to allow firm conclusions to be drawn, but it is interesting to note that late summer and early winter rainfall were both considerably higher in 2015 than in both 2016 and the long-term mean (Figure 1a). Breeding in Australian birds in arid and semi-arid areas is strongly influenced by rainfall (e.g. Carnaby 1954; Keast and Marshall 1954) and it is likely that the significant rainfall events on Dirk Hartog in 2015 stimulated a lot of activity (territory defence, breeding activity, young birds) that would have contributed to the conspicuousness of birds during the time we were sampling. If breeding was successful, it would be expected that the population would have increased, but that is not evident in the 2016 data. However, summer of 2015-16 was abnormally dry (Figure 1) and it is possible that very few young birds survived into the winter of 2016.

There is evidence to support this conclusion from the population monitoring of White-winged Fairy-wrens on Barrow Island (Chevron Australia 2015). This population (*Malurus leucopterus edouardi)* is another island endemic with black and while males. Population estimates varied markedly between 2009 and 2014 (Table 3); for example, the population estimate in 2010 was only 34% of what it was the previous year, and the lowest population estimate was 32% of the highest. It is not known what causes these variations, but they are believed to be related to a variety of factors, and may include rainfall, bird behaviour and fire impacts. On Dirk Hartog Island there were no signs of recent fire in any of our survey areas when we were sampling, and there were no significant changes in density of grazing animals during the period we were surveying, so it is likely that the changes we observed were due to rainfall.

Parameter	2009	2010	2011	2012	2013	2014
Density estimate (individuals/km^2)	53.22±10.33	18.37±3.26	31.50±5.42	45.47±8.34	28.00±4.72	17.32±4.26
Population estimate (individuals)	12,524±2431	4317±765	7412±1275	10,684±1960	6579±1110	4009±986

Table 3. Estimates of population density and total abundance of White-winged Fairy-wrens on Barrow Island, 2009-2014. (Data from Chevron Australia 2015).

The observed levels of variation mean that it would be challenging to use monitoring data for these species to evaluate any management action, without having a long-term data set that allowed estimation of the impact of year to year variation in factors such as rainfall.

An additional challenge is that, because each species occurs in family groups, the abundance estimates for each are sensitive to estimates of group size. This can be difficult to determine in species that are hard to detect, and is particularly difficult with the emu-wren, which is highly cryptic. Targeted study of group sizes in each of these species would assist in gaining insight into the accuracy and interpretation of these figures.

Conclusions

The density surface models provide a sound basis for a range of management decisions, for example with respect to questions such as the placement of fire breaks, which would be best placed in areas where there are natural breaks in the distribution and abundance of, especially, the Southern Emu-wren. The variability between years is particularly challenging in relation to being able to draw firm conclusions from monitoring, but the relatively large total population sizes for each species means that they are likely to be reasonably resilient, and all species surveyed were widespread on the island, suggesting that individual management actions with a small footprint are not likely to have a large population impact. Previous broad scale impacts (introduced grazing animals and feral cats) have now been removed from the island, and so future potential impacts are likely to be localised. Given the known abundance and widespread occurrence of the threatened bird species on the island, they should all be relatively secure. However, it will be important to continue monitoring (van Dongen and Huntley 2017; S. Cowen pers. comm.) potential impacts of translocated native mammals and their interactions with vegetation and other animal species, to ensure that vegetation (habitat) condition is maintained.

The high variability in the bird population estimates between years means that it will be challenging to design and implement monitoring programs that are capable of distinguishing natural variations (e.g. due to weather) from the impact of management actions. Getting enough data to draw firm conclusions would be very resource-intensive, and require suitably experienced observers.

Distance sampling provides robust estimates of population size and density. However, under current levels of resource availability, it is not likely to be a practical alternative for routine monitoring. A simpler occupancy approach would be easier to implement for routine monitoring, but this will only provide a very coarse estimate of population trend. For management decisions to be made with confidence, the threatened species should be monitored in more detail (using distance sampling) at five year intervals.

Further work could focus on understanding the underlying drivers of change in distribution and abundance of the threatened birds on Dirk Hartog Island, using the detailed 2015 and 2016 data as well as earlier habitat preference data. This may assist in identifying key areas of focus for each species in a simplified sampling or monitoring program.

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Appendix 1. Threatened and rare terrestrial bird taxa known from Dirk Hartog Island. 'Action Plan status' is from Garnett *et al*. (2011).

Common name	Scientific name	Action Plan status	EPBC status	WA status	Range
Dirk Hartog Island Black-and-White Fairy-wren	*Malurus leucopterus leucopterus*	VU	VU	Schedule 1 (VU)	endemic to Dirk Hartog Island
Dirk Hartog Island Southern Emu-wren	*Stipiturus malachurus hartogi*	VU	not listed	Schedule 1 (VU)	endemic to Dirk Hartog Island
Western Grasswren (Shark Bay subspecies)	*Amytornis textilis textilis*	LC	not listed	P4	restricted to Shark Bay area; possibly extinct on Dirk Hartog
Dirk Hartog Island Rufous Fieldwren	*Calamanthus campestris hartogi*	VU	not listed	Schedule 1 (VU)	endemic to Dirk Hartog Island

Note: About 12 species of threatened or near-threatened shorebirds also occur, and the Fairy Tern (VU) breeds on Dirk Hartog Island and Meade Island.