Landbirds on Lord Howe Island, NSW

Survey report 6

September 2019



Prepared for the Lord Howe Island Board

by the Canberra Ornithologists Group

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November 2019

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Summary

This report describes a survey in September 2019 of landbirds on Lord Howe Island conducted by the Canberra Ornithologists Group (COG). The survey was the sixth assessment of the status of landbirds on the island. This survey has been commissioned by the Lord Howe Island Board as part of the necessary monitoring processes associated with the project to eradicate rodents from the island.

The purpose of the survey is to provide baseline information on the numbers and distribution of landbirds on Lord Howe Island and to assess changes that occur after rodents are no longer present. Plot counts were chosen as the preferred method for the island survey. The data collecting protocol used is one we believe best fits the limitations of time and effort available in the field. Transects surveys were conducted on six evenings, concentrating on the most important ground feeding species present in the settlement area.

As for the earlier surveys, 48 paired plots were selected across the survey area. The plots were stratified to represent various vegetation types and habitat zones with seven transects selected within the settlement area. From experience gained during the 2013 survey, four teams of two observers surveyed all paired plots in three days with all of the plots resurveyed over the following three days.

The mean abundance, mean reporting rate, frequency and group size for each of the 18 species recorded during the plot survey were calculated. In addition, the 13 species were analyzed using generalized linear mixed models, allowing both fixed and random effects to be taken into account. Maps of species distribution for 14 species with sufficient data are presented and can be compared with similar maps prepared in 2013, 2014, 2016, 2017 and 2018.

From the 2013, 2014, 2016, 2017, 2018 and 2019 surveys, 25 bird species have been recorded from the plot counts. Two species (Woodhen and Pied Currawong) were not generally available for counting in 2019 because the majority of them were being held in captivity at the time of our survey. In addition to the Woodhen and Pied Currawong, the White-faced Heron, Buff-banded Rail, Swamphen, Masked Lapwing, Emerald Dove, Sacred Kingfisher, Golden Whistler, Magpie-lark, Silvereye, Common Blackbird and Song Thrush have been reported from the counts for each of the survey years. Welcome Swallow has been reported for all surveys apart from 2013 whilst the Kestrel was reported for 2014 and 2018. Feral Duck and Feral Pigeon were not reported for 2014. Whimbrel has been reported in 2016, 2017 and 2018. Starling was reported for 2013, 2018 and 2019, Bar-tailed Godwit for 2014 and 2018, Cattle Egret for 2016 and 2017 with Red-necked Stint for 2014 only and Golden Plover and Double-banded Plover only for 2018. New for 2019 was the Tree Martin.

Comparing the reporting rate of the more common species between 2018 and 2019 but excluding consideration of Woodhen and Pied Currawong, there appears to have been a decrease in many species including the Buff-banded Rail, Masked Lapwing, Emerald Dove, Sacred Kingfisher, Golden Whistler, Silvereye and Blackbird and little change for the remaining species. The Golden Whistler followed by the Silvereye continues to be the most common species.

In general, where the habitat influences are included in the generalized linear mixed models they appear to be sensible and generally reflect what we know about the biology of the species. In comparison to the previous reports, and with additional data, there is less potential difference between years than was noted for last year's report. Additional modelling may be necessary to clarify if this is a general result.

For the transect surveys, and with the additional year of survey, of the six species reported here four, Emerald Dove, Sacred Kingfisher, Song Thrush and Woodhen now show evidence of differences between the years of survey and the models suggest that the current survey effort is able to detect changes over time. The interpretation of the apparent influence of the direction of travel along the transects needs further analysis but would appear to be driven by the period of the traverse relative to sunset. Emerald Dove and Sacred Kingfisher abundances are significantly higher for the outward traverse compared to the inward count. This is in contrast to the Blackbird where the inward count yields a larger number of individuals recorded. For the 2018 survey an additional observer surveyed all transects in reverse, with two observers starting at opposite ends of the transect. Also, the additional observer surveyed transects in the early morning on six days.

The protocol for the surveys provides a rigorous method for obtaining statistically sound measures of significant changes in population numbers and distribution of species over time – particularly changes occurring after rodent eradication.

Except for the Buff-banded Rail, the various models for the plot and transect surveys do not support any year effect when compared with 2019. This indicates that the rodent eradication project has not had any significant direct effect on any bird species surveyed except for the Buff-banded Rail.

In Appendix E we present a preliminary analysis to explicitly define impacts of rodent baiting protocol on adult bird mortality and with additional data a more definitive analysis may be possible.

The timing of the survey in relation to baiting during the rodent eradication project and changes in habitat and food resources caused by the removal of some livestock may have affected non-target species in ways that cannot be measured unless surveys are repeated in 2020 and possibly 2021.

Introduction

This report describes a survey in September 2019 of landbirds on Lord Howe Island (latitude 31° 33´S and longitude 159° 05´E). The survey was the sixth annual assessments of the status of landbirds on the island and was conducted following shortly after completion of the main work of a rodent eradication project that started in June 2019. Previous surveys, conducted in 2013, 2014, 2016, 2017 and 2018 have been reported (Fullagar *et al*., 2014, Fullagar *et al*., 2015, Fullagar *et al*., 2017, Fullagar *et al*., 2018, Fullagar *et al*. 2019).

These surveys have been commissioned by the Lord Howe Island Board as part of the necessary monitoring processes associated with efforts to eradicate rats and mice from the island.

The purpose of past surveys has been to provide baseline information on the numbers and distribution of landbirds on Lord Howe Island. Landbirds are here defined as those species that are either breeding residents on the island or land-based visitors. Specifically, all seabirds are excluded but shorebirds are not.

The bird surveys were started on 10 September, that is just under 9 weeks after the aerial baiting with some hand baiting still occurring during the bird survey period (see more details below). A rigorous survey method has been used to provide data that can give a statistically sound measure of significant changes in population numbers and distribution – if they occur.

As indicated in the first report (Fullagar *et al.*, 2014) point counts were chosen as the preferred method for the island survey. Much of the vegetation is dense and often difficult to access; repeated line transects would have been difficult to follow in such circumstances. Plot counts are easier to incorporate in a formally designed study, easier to locate and lay out, and they provide a more reproducible data set. As well, point counts are more efficient than transect counts because they allow for more data points (Bibby *et al.*, 1997).

We investigated the power of available statistical analyses achievable with this point count method of population assessment (Nicholls, unpublished) and adopted the data collecting protocol we believe best fitted the limitations of time and effort available in the field. As an additional data set we did, however, use a simple transect procedure to assess the abundance of species within the most closely settled area of the island. These transects were walked at dusk (and for a small sample at dawn) using the network of sealed roadways.

For a review of the historical records of birds on Lord Howe Island see Fullagar *et al.*, 2014.

Rodent Eradication Project

Investigation into the feasibility of a project to remove rodents (Roof Rat *Rattus rattus* and House Mouse *Mus musculus*) from the island began in 2001; the first draft plan was drawn up in 2009, and funding achieved in 2012. Following extensive environmental and human health assessments of this proposal, the Lord Howe Island Board voted to proceed with the project in 2017. Finally, in 2019 the project was implemented.

The methods used were those that had evolved over nearly 40 years of island rodent eradication projects around the world. The experience and the science from these earlier projects was incorporated into the Lord Howe island Rodent Eradication Plan, with review by international experts in this field.

The methodology was to expose every rat and mouse on the island to a cereal bait containing the active ingredient '*brodifacoum*', an anticoagulant. The bait used was '*Pestoff*' 20R, a cereal pellet incorporating the active ingredient *brodifacoum*.

To achieve this on an inhabited island, four methods were used to deliver the baits.

- Away from the settlement helicopters were used to distribute bait pellets very accurately to the ground, at an application rate of 12 kg per hectare.

- In the settlement area with dwellings, paddocks and native vegetation, a network of bait stations was used with a bait station on the ground every ten metres. This equated to approximately 19,800 bait stations.

- In all buildings, smaller bait stations were used to expose all mice to a bait, with each room having a bait station. Roof cavities were also baited and for those roof cavities without internal manhole access, baits were installed by lifting roof sheeting.

- In between the areas treated with bait stations and in the mountains, areas of pastures were treated by workers hand broadcasting bait pellets, at ten metre intervals, in the first week of June.

In April the empty bait stations were deployed across the settlement using differential GPS (Global Positioning System) for high accuracy and placement under the forest canopy.

To ensure no endemic birds were harmed by *brodifacoum*, the project included the capture and captive management of Woodhen and Pied Currowong. During April and May 2019 staff from Lord Howe Island Board and the NSW Department of Planning, Industry and Environment caught 225 Woodhens and 122 Pied Currawongs and brought them to specially

designed aviaries constructed on the island. This work was completed by 24 May. Staff from Taronga Park Zoo were on the island from April through to November to care for these captive birds.

Bait stations were prepared and hand broadcasting of baits was carried out from 21 May, after the Woodhens and Pied Currawongs had been successfully housed in their aviaries. In June, two helicopters arrived on the island, in preparation for aerial distribution of pellets. The first of these applications began on 6 June, and the second application was in the first week of July. Final aerial and hand broadcast baiting was completed by 12 July.

Hand baiting was continued each week in the settlement area by topping up the bait stations using the same *Pestoff* 20R pellets. All baiting stations were checked and replenished every 7 to 10 days. Additional hand broadcasting (where bait stations were still having active bait take or rodent activity had been reported) was completed by 23 August. Final baiting in ground bait stations was completed by 1 November.

Removal of introduced Masked Owls was a part of the project, and it was deemed essential to remove all of these birds that were introduced in the 1920's to eat the rats. With the rodents gone, the owls would switch to eating seabirds and Woodhens. It was believed 40 to 50 Masked Owls were living on the island, and 14 were found dead from secondary poisoning. A team of professional shooters, and locally trained shooters was engaged to eradicate them totally.

A Technical Advisory Group had been set up to provide technical advice to the Lord Howe Island Rodent Eradication Steering Committee and be responsible for providing advice and recommendations for the development and implementation of the Monitoring and Mitigation Plan to minimise the impacts from aerial baiting on non-target species and the environment in relation to the Lord Howe Island Rodent Eradication Project.

The committee met weekly to review weekly reports regarding non-target species mortality and efficacy of carcass searches and removal for a period of 4 months after the baiting started.

Non-target species searches were conducted in accordance with the Environment Protection and Biodiversity Conservation (EPBC) Mitigation and Monitoring Plan and the Australian Pesticides and Veterinary Medicines Authority (APVMA). Risk Mitigation Plan. Permit listed species refer to those listed in the EPBC Mitigation and Monitoring Plan (Golden Whistler, Silvereye and Pied Currawong) and additional species listed in the APVMA Risk Management Plan (Buff-banded Rail, Swamphen, Australian Kestrel, Sacred Kingfisher, and Pacific Black Duck).

The 2019 landbirds survey was conducted between 10-16 September, that is 60 days after the aerial baiting although some strategic hand baiting was still occurring during the landbirds survey period.

Breakdown of the *Pestoff* pellets was monitored, and when no whole baits remained on the ground and the killed rodents had decomposed, the release of captive Pied Currawong began. Captive Pied Currawongs were released in a staged process. Five pairs fitted with radio transmitters on their tails were released in the first week of September and after a period of two weeks with all of those birds surviving it was assumed the environment was safe to release the remaining birds.

Woodhen were ferried to the remote areas of the island – Mount Gower, Mount Lidgbird and Big Slope during the week 12-17 November. All remaining Woodhen were released by walkers from 17 November.

Ground baits stations were removed in November 2019. The project of monitoring for any residual rodents using detection devices and sniffer dogs continued to mid-December.

Monitoring will continue with detection devices and dogs. In two years time an island wide search effort with specially trained sniffer dogs will determine if the projects has been successful.

Methods

As previously this report clarifies some terms used in some past reports by renaming them and by defining the term 'survey':

- **count –** data collected by a single observer from a single plot or traverse of a transect on a single occasion.
- **grid** – a group of cells 500 m x 500 m within which a pair of plots is located.
- **paired plot –** replaces paired site.
- **plot** – replaces site; a location defined by vegetation group and habitat zone, covering an area of 50 m radius; plots are paired, a minimum of 100 m apart and within the same vegetation group, habitat zone and grid cell.
- **plot count** – a method of recording observed species.
- **record** – a documented observation of a single species defined by date, plot or traverse of a transect and the number present (seen/heard).
- **survey** – recorded observations for a given period on the island; usually seven days.

Choice of plots

For practical reasons, determined by the time available for surveying and the number of teams we could muster, only the northern part of Lord Howe Island was included. Mt Lidgbird and Mt Gower were excluded, as were Erskine Valley and any of the mountain slopes below the peaks beyond Mutton Bird Point and Little Island (see Figure 1).

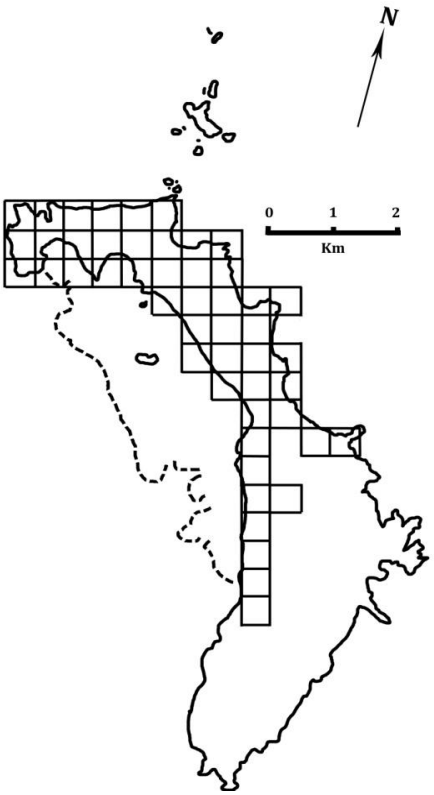


Figure 1. Grid cells, based on plot counts, used for surveying distribution of landbirds on LHI, September 2019

The same 48 grid cells (see Figure 1) used in previous surveys were surveyed again in 2019, and each grid cell was allocated two count plots. The plots were stratified to represent the various vegetation types and habitat zones. For a description of paired plots defined by vegetation and habitat classification see Appendix A. There was no survey in 2015 because all field monitoring projects were put on hold by the Lord Howe Island Board while community consultation regarding the rodent eradication took place.

Plot count protocol

Our protocol involved four teams of two observers surveying over six days. Surveying was restricted to between sunrise and late morning and, as in 2014, 2016, 2017 and 2018, each

team surveyed eight plots per day. All 96 plots were surveyed in three days with a repeat of all plots over the following three days. Due to wet and windy conditions plot 16 was not surveyed on 13 September giving a total of 383 plot counts.

The paired plots were a minimum of 100 m apart and similar in topography and vegetation. See Appendix B for plot details of geolocation, vegetation and habitat type and number of surveys for each of the 96 surveyed plots. No plot was resurveyed by the same observer.

The count protocol at each plot was to record the abundance of each species seen or heard within a 50-metre radius over a 10-minute period, with observers moving within the plot area if required. Team members would survey a pair of plots independently and simultaneously before swapping plots and again counting for 10 minutes.

Only experienced observers were chosen for the field work. All team members were well-trained, expert bird watchers with considerable previous involvement with similar style field work.

In the field the location of the paired plots was determined by GPS. Due to difficulties of terrain and differences in vegetation it was often not possible to plot count at the exact pre-determined point. Observers were requested to plot count as near as they could to the allocated point. On arrival a waypoint reading was taken of the actual point of the plot and subsequently compared with the intended point of the plot.

Statistical treatment of plot counts

Several summary parameters were used as population indices and these will become useful for comparison with data collected in future.

- Mean abundance (A). The average number of individuals of a species seen per observation and defined as the sum of the number of individuals reported divided by the total number of observations (383).
- Mean reporting rate (R). Defined as the number of recorded occurrences divided by the total number of observations (383).
- Frequency (F). The plot occupancy rate or incidence rate defined as the number of plots on which a particular species was recorded divided by the total number of plots (96).
- Group size (G). Defined as the sum of the number of individuals divided by the number of observations in which a species was recorded.

Statistical model of plot counts

A generalized linear mixed model was the starting point for the analysis of the combined (2013, 2014, 2016, 2017, 2018 and 2019) data. We have accounted for the non-normal distribution of the counts and the structural components of the survey design. We assume that the counts are drawn from Poisson distributions. The fixed effects explored are vegetation group, (a three-level factor) derived from the vegetation type (see Appendix A), year, primarily to test if there has been any detectable change over the 12-month intervals between surveys and starting time (the recorded time of the start of the plot count). The random effects include plot, observer and day when the survey was performed. In previous years we have included zone as a random factor but current advice is that factors with few levels could be better treated as a fixed effect. This course of action has been followed here.

All models were fitted using the R software (R Core Team, 2015) and the package 'lme4' (Bates *et al.*, 2014). Where possible, confidence intervals were derived from the models using functions from the 'lme4' package. In some cases numerical instability of the parameter estimation prevented fitting of complete models with all fixed terms. In these cases simpler models were fitted.

As in the past, due to the difficulty in collecting reliable abundance data for Silvereye, only presence or absence data are available. Appropriate models fitted to these data assume a binomial error structure and a logit link function.

Transect surveys

The same seven transects covered in September 2013, 2014, 2016, 2017, 2018 and of variable length (ranging from 570 to 970 metres) were walked in 2019 at a slow pace by a single observer twice – in one direction (out) and then return (in) – in the evening on six days. As with 2013 and 2014, seven observers were available for the transect surveys. See Fullagar *et al.* 2017 for details of the 2016 transect survey and Fullagar *et al*. 2018 for the 2017 transect survey. For the 2018 and 2019 surveys an additional observer surveyed all transects in reverse, with the two observers starting at opposite ends of the transect. Also, the additional observer surveyed transects in the early morning on the following six days. The transects followed sealed roads. To reduce the variability of speed of travel, each transect was set a specific duration for survey with a walking pace set at 2 km/hr.

Figure 2 provides a map of the Lord Howe Island core settlement area, showing the location of transects A–G. The green pointers indicate junctions, where more than one transect starts or finishes. The yellow pointers indicate transect end points. See Appendix C for a description of the start and finish points for each transect.

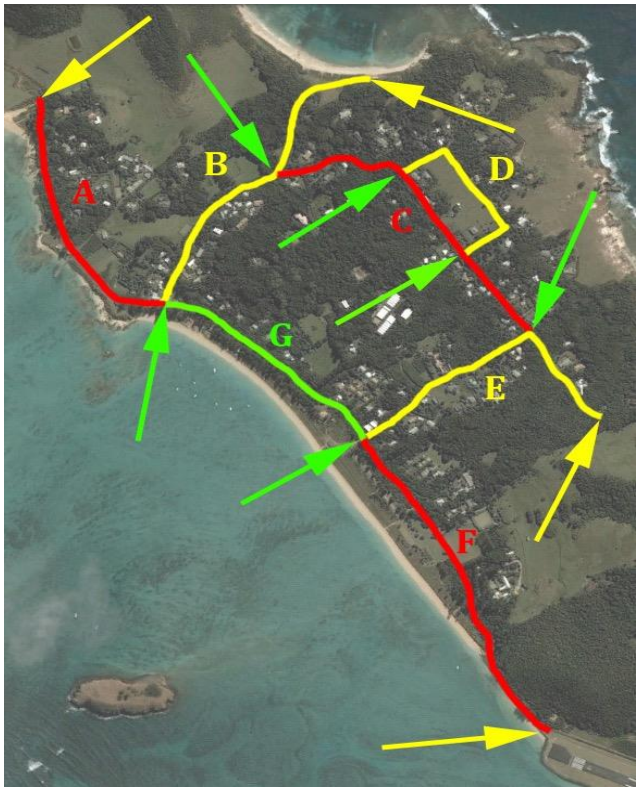


Figure 2. Map of core settlement area, LHI, with location of transects (A–G)

None of the observers walked the same transects twice, with seven observers covering six of the seven transects (see Table 1). For this 2019 year all species were counted while surveying these transects – rather than the six species selected for counts in the past.

Table 1. Allocation of observers to transects, LHI core settlement, September 2019

Observer	*Transects*						
	A	B	C	D	E	F	G
Ob1	1	1	0	1	1	1	1
Ob2	1	1	1	0	1	1	1
Ob3	1	1	1	1	0	1	1
Ob4	1	1	1	1	1	0	1
Ob5	1	1	1	1	1	1	0
Ob6	0	1	1	1	1	1	1
Ob7	1	0	1	1	1	1	1
Ob8*	1	1	1	1	0	1	1
Ob8**	1	1	1	1	0	1	1
Length (m)	*750*	*970*	*900*	*570*	*820*	*970*	*670*

Note: Observers not necessarily the same for 2013, 2014, 2016, 2017 and 2018.
* Additional observer (see page7 for details).
** Additional observer for morning count (see page 7 for details).

Statistical analysis of transect data

There are two groups of potential predictors of the abundance of the observed species. The first group characterizes the observations in terms of physical characteristics of the transect (length), the direction of the traverse (out or in) and the duration of the count (duration) or the average speed of travel (speed). These physical characteristics are all connected.

More individuals would be expected to be observed on longer transects, or during longer travel times or slower speeds of travel; there is no a priori reason to think that direction of travel should influence the number of individuals observed. Also in this group is the year of observation, which potentially reflects changes over time scales of a year or more. The second group of predictors includes observer identity, transect identity and date of observation.

It is recognized that there are observer differences in terms of ability to detect individuals of different species. It is also recognized that transect differences will favour more individuals on some transects relative to other transects and some days will be better than others for making observations.

We are not primarily interested in the effects of the second group of predictors but need to account for the variability in observations that can be attributed to these factors. We do this by considering observer identity, transect identity and date of observation as random effects. Of the first group, year of observation is of primary interest; the others may need to be accounted for to reduce the unexplained variation.

The response variable – the number of individuals per species observed per transect survey – can be considered a Poisson variable where the variance is equal to the mean. To model the observed data we need to fit generalized linear mixed models to account for the variance structure of the residuals and the presence of both random and fixed effects. Models were fitted using R (R Core Team, 2015) and the package 'lme4' (Bates *et al.*, 2014). As for the point data, estimates of the mean number of individuals observed per transect and confidence intervals were derived from parametric bootstrapping techniques based on functions supplied with the package 'lme4' and the package 'boot' (Canty and Ripley, 2014).

Species names

Species names used in this report follow current preferred internationally accepted nomenclature (see Appendix D). For simplicity, some of the common names have been shortened to conform with island usage.

Survey dates and weather conditions

The flight from Canberra to Sydney was cancelled for 24 hours due to high winds in Sydney. The start of the survey was delayed for one day but a spare morning on the 16 September

before the afternoon departure flight allowed both the point count and the transect surveys to be completed.

The 2019 plot counts were surveyed between 11 and 16 September with the transect surveys conducted between 10 and 15 September, and the final morning transect survey conducted on 16 September. For the point count surveys, teams were in the field soon after dawn each day and ready to start by about 06:00. Teams often worked through until late morning. The time to complete a set of counts varied mostly due to the time taken to reach all allotted count plots. The evening transect surveys, however, started at 17:00 each day with the morning surveys starting at 6:30.

The weather for the point counts was generally cool with slight winds clearing to sunny conditions on most days. On the morning of the 13th there was a frontal passage which brought showers resulting in one of the 384 plots not being surveyed.

For the evening transect counts the weather was generally fine but with breezy to strong winds at times on all days. The passage of fronts on the 10 September and again on the 14 September produced windy conditions on all transects. Some weather observations for the week are shown in Table 2.

Table 2. Selected daily weather observations, LHI, 10–16 September 2019

Date	*Day*	*Min °C*	*Max °C*	*Rain (mm)*	*Wind Direction*	*Max. wind speed (km/h)*
10	Tue	12.8	18.4	2.4	SSW	57
11	Wed	13.9	19.2	1.2	SW	54
12	Thu	12.1	19.6	0.0	WNW	22
13	Fri	14.2	19.9	0.0	W	48
14	Sat	14.9	19.3	3.8	WSW	39
15	Sun	16.0	18.9	0.2	SW	43
16	Mon	11.0	20.8	0	WNW	39

Source: Bureau of Meteorology website

Results

Plot counts

The maximum number of times that any one species could be recorded was 383: the sum of 95 plots with four plot counts and one plot with 3 counts. Table 3 shows the distribution of the counts in the vegetation groups and habitat zones.

Table 3. No. of counts undertaken in 3 vegetation groups in 5 habitat zones, LHI, 2019

Vegetation group	*Habitat zone*					***Total counts***
	1	*2*	*3*	*4*	*5*	
Lowland forest	103	24	32	16	32	**207**
Palm forest	8	56	8	0	32	**104**
Open	0	32	4	32	4	**72**
Total surveys	**111**	**112**	**44**	**48**	**68**	**383**

Note: For definitions of vegetation group and habitat zone, see Appendix A.

Abundance, reporting rate, frequency and group size

Table 4 shows the abundance, reporting rate, frequency and group size, irrespective of vegetation group or habitat zone, for 22 birds recorded in 96 plots in 2018 (Table 4a) and for the 18 species recorded in 2019 (Table 4b). For ease of comparison species in Table 4a are listed in order of reporting rate whilst species in Table 4b are listed in the same order as in Table 4a.

As occurred in 2013, 2014, 2016, 2017 and again in 2018, the most common bird in terms of reporting rate and abundance was the Golden Whistler. The number of Silvereye individuals on a plot was difficult to estimate given their flocking behaviour, their often quick passage through the plots and the fact that they were usually detected only by calls. For the Silvereye, only occurrence was analyzed and no estimate of abundance or group size was possible.

There were no records of the Golden Plover, Whimbrel, Bar-tailed Godwit, Kestrel or Double –banded Plover in the plot counts for 2019. An additional species, Tree Martin, was recorded in 2019. There was a single record of a Woodhen in 2019; however, most Woodhen were held in captivity at the time of this survey.

A comparison of abundance indicated lower numbers in 2019 for the Golden Whistler, Pied Currawong, Common Blackbird, Magpie-lark, Welcome Swallow, Sacred Kingfisher, Emerald

Dove, Buff-banded Rail and Masked Lapwing whilst the reporting rate showed little difference between 2018 and 2019 for the Golden Whistler and Silvereye with the Pied Currawong, Common Blackbird, Sacred Kingfisher and Buff-banded Rail all showing a large decrease in 2019 compared with 2018. A significant number of Pied Currawongs were of course in captivity at the time of our survey.

Table 4. (a) Abundance, reporting rate, frequency and group size for 22 bird species recorded at 96 plots, LHI, 2018 and (b) the equivalent information from 2019

a

Species name	*Abundance*	*Reporting rate*	*Frequency*	*Group size*
Golden Whistler	1.78	0.75	0.89	2.38
Silvereye		0.70	0.88	
Pied Currawong	0.55	0.30	0.56	1.83
Blackbird	0.59	0.29	0.52	2.02
Magpie-lark	0.41	0.20	0.32	2.04
Welcome Swallow	0.62	0.19	0.31	3.32
Sacred Kingfisher	0.17	0.14	0.36	1.23
Emerald Dove	0.16	0.13	0.34	1.30
Buff-banded Rail	0.17	0.10	0.25	1.64
Woodhen	0.07	0.08	0.17	1.17
Masked Lapwing	0.06	0.04	0.07	1.71
Golden Plover	0.25	0.03	0.05	7.08
Song Thrush	0.03	0.03	0.08	1.08
White-faced Heron	0.03	0.02	0.07	1.11
Starling	0.06	0.02	0.06	2.63
Feral Duck	0.03	0.02	0.04	1.86
Swamphen	0.05	0.01	0.03	4.25
Feral Pigeon	0.02	0.01	0.03	2.00
Whimbrel	0.01	<0.01	0.01	4.00
Bar-tailed Godwit	0.01	<0.01	0.01	2.00
Kestrel	<0.01	<0.01	0.01	1.00
Double-banded Plover	<0.01	<0.01	0.01	1.00

b

Species name	*Abundance*	*Reporting rate*	*Frequency*	*Group size*
Golden Whistler	1.25	0.66	0.84	1.88
Silvereye		0.70	0.91	
Pied Currawong	0.07	0.04	0.15	1.47
Blackbird	0.33	0.18	0.52	2.02
Magpie-lark	0.22	0.14	0.32	1.59
Welcome Swallow	0.83	0.21	0.36	3.90
Sacred Kingfisher	0.10	0.08	0.25	1.23
Emerald Dove	0.24	0.17	0.38	1.40
Buff-banded Rail	0.04	0.03	0.08	1.25
Woodhen	0.00	0.00	0.01	1.00
Masked Lapwing	0.01	0.01	0.03	1.00
Golden Plover				
Song Thrush	0.05	0.04	0.09	1.43
White-faced Heron	0.02	0.01	0.04	1.40
Starling	0.03	0.02	0.06	1.43
Feral Duck	0.00	0.00	0.01	1.00
Swamphen	0.01	0.01	0.02	1.00
Feral Pigeon	0.01	0.01	0.02	1.00
Whimbrel				
Bar-tailed Godwit				
Kestrel				
Double-banded Plover				
Tree Martin	0.00	0.00	0.01	1.00

Table 5 shows the 2019 reporting rate, abundance and frequency for the most commonly reported species – the Golden Whistler – and the Pied Currawong, although many of this species were held in captivity at the time of this survey. The three indices for observations within the plots are defined by vegetation and habitat zone. No useful data was available for Woodhen because most were held in captivity at the time of the survey.

Table 5. Reporting rate, abundance and frequency for the Golden Whistler and and Pied Currawong, defined by vegetation group and habitat zone, LHI, 2019

Golden Whistler

	Reporting rate			*Abundance*			*Frequency*		
Vegetation group	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Habitat zone									
1	0.76	0.13		1.38	0.13		0.27	0.01	
2	0.83	0.80	0.06	1.58	1.50	0.09	0.06	0.14	0.02
3	0.91	0.88	0.50	1.63	1.75	0.50	0.08	0.02	0.01
4	0.94		0.25	2.50		0.31	0.04		0.04
5	0.94	0.53	0.00	1.94	0.91	0.00	0.08	0.06	0.00

Pied Currawong

	Reporting rate			*Abundance*			*Frequency*		
Vegetation group	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Habitat zone									
1	0.03	0.00		0.03	0.00		0.03	0.00	
2	0.04	0.04	0.03	0.04	0.05	0.13	0.01	0.02	0.01
3	0.13	0.13	0.03	0.16	0.13	0.13	0.03	0.01	0.00
4	0.19		0.00	0.31		0.00	0.02		0.00
5	0.00	0.06	0.00	0.00	0.09	0.00	0.00	0.01	0.00

Note: Empty cells indicate that no vegetation group exists for that habitat zone.

Similar to previous surveys for the Golden Whistler, the highest reporting rate and abundance was in vegetation groups 1 (*Drypetes, Cassinia-poa*) and 2 (Pasture*/Howea forsterana, Syzygium fullagarii*), and habitat zone 2 (Settlement) and habitat zone 3 (Transit Hill).

For the Pied Currawong the highest reporting rate and abundance was in habitat zone 4 (Suburban), vegetation group 1 (*Drypetes/Crypyocarya*) followed by habitat zone 3 (Transit Hill) and vegetation group 1 (*Drypetes/Crypyocarya*). This differs from 2018 where the most common reporting rate and abundance were in habitat zone 5 (South Hills). This change in distribution is reflected in Figure 15 of this report compared with the 2018 report, see Fullagar *et al*. 2019, Report No. 5.

Generalized linear mixed models

It is recognized that generalized linear mixed models can be difficult to fit even with well-designed and generally balanced surveys. In the present study the number of random effects contributes to the complexity of the models. The small number of individuals recorded at each plot also adds difficulties to the parameter estimation. For some species the estimated confidence intervals are clearly very wide and appear to be well outside the observed data. This reflects some of the complexities of these models. Even with the additional data from the sixth survey in 2019 some of these difficulties remain.

To allow for a statistical comparison of the survey data pre- and post-rodent eradication, fixed effects such as vegetation type and year of survey together with random effects such as plot, zone, observer and day differences will need to be taken into account. The development of increasingly powerful software for fitting generalized linear mixed models is making the fitting of more complex models possible.

Data from the five surveys, 2013, 2014, 2016, 2017, 2018 and 2019 were combined and analyzed. Note that the model for Silvereye is fitted to the presence–absence data while for all other species the model is fitted to the abundance data. The results of the generalized linear mixed models are summarized as follows:

- the significant fixed effects are listed for each species,
- the magnitude of the random effects are described,
- the estimated abundances and where possible the confidence intervals derived from the appropriate model are graphically presented and
- species specific information on issues is described with the fitting and interpretation of the model.

The fixed effects, zone and vegetation group, are significantly associated with five of the 13 species for which generalized linear mixed models were fitted and tested. No species showed significant differences between years. The abundance of these species were associated with the starting time of the plot count, with three – Buff-banded Rail, Swamphen, Emerald Dove - showing reduced abundances as the interval from sunrise increased.

The magnitude of the random effects describe the variability of the observations with respect to plot (also accounts for repeat observation on the same plot), observer, the day on which the count was undertaken (can account for conditions that are otherwise unrecorded, e.g. weather conditions) and zone (which can account for environmental influences not captured by the fixed effect of vegetation group). The two largest sources of

variation are plot (largest for five of the 13 species) and zone (largest for the other six species).

Woodhen

There appears to be a single important fixed effect, Zone. Zones 4 and 5 have higher predicted abundances than the other three zones. See Figure 3.

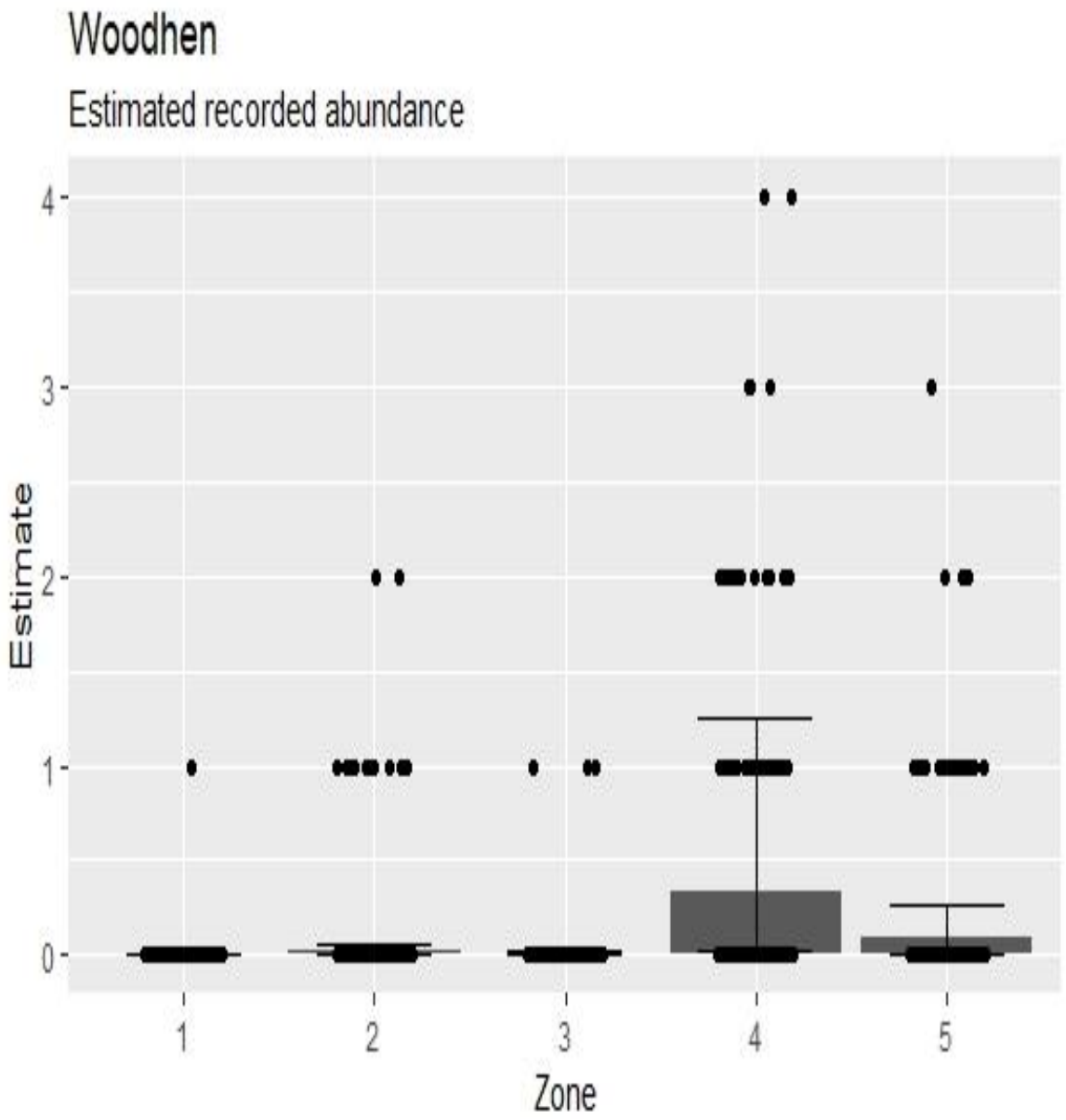


Figure 3. Estimated number of Woodhen as a function of the zone in which the plot exists

There was no year effect between 2013 and 2018. For 2019 there was a single observation so a major effect (reduction) when compared with other surveys.

Buff-banded Rail

The single fixed effect Zone appears to be the most important. The selected model (see Figure 4) illustrates the effect Zone on the expected abundance.

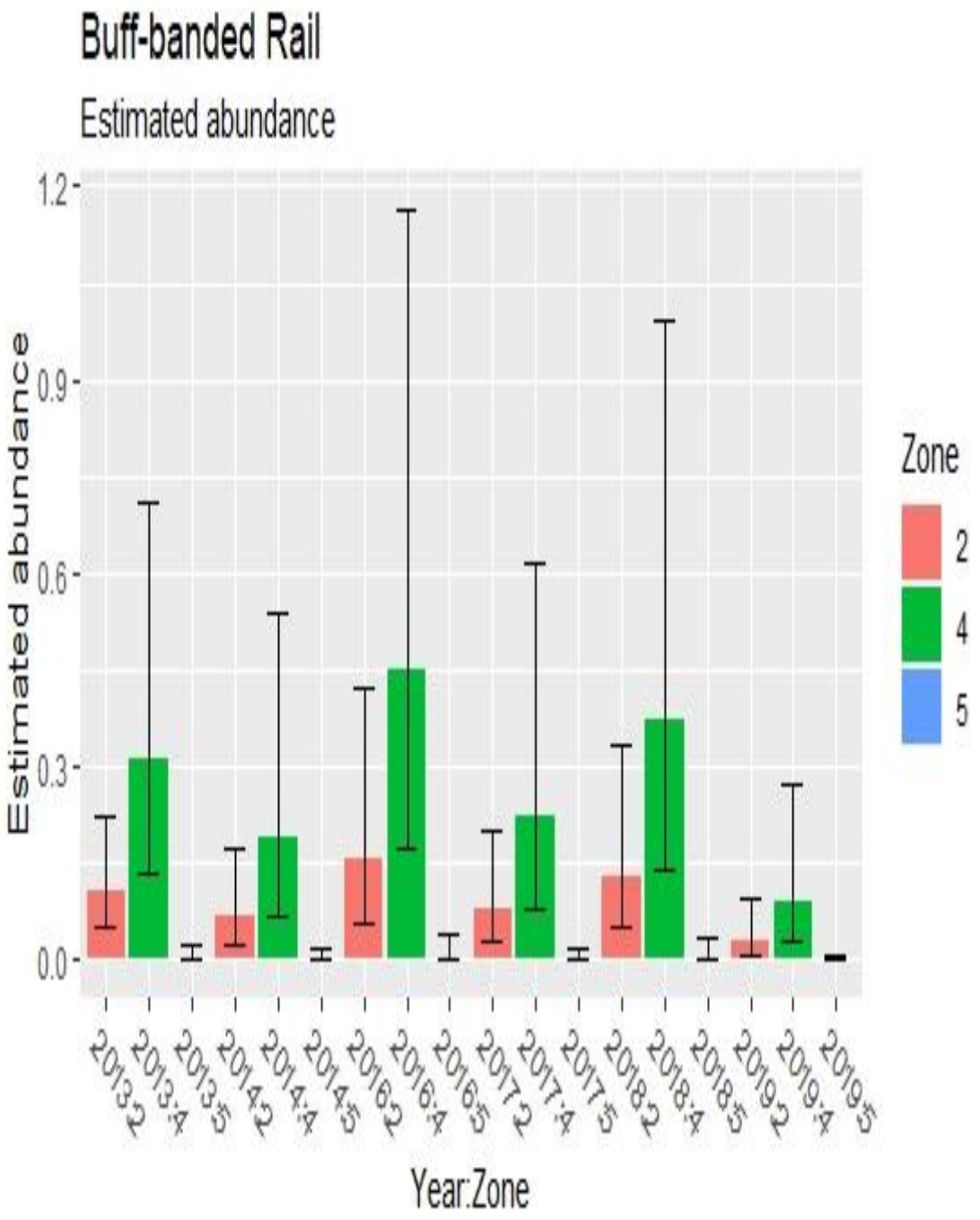


Figure 4. Estimated number of Buff-banded Rail as a function of the year of survey and the zone in which the plot exists

There was a year effect with 2019 significantly lower than all previous surveys.

Swamphen

While a model has been fitted to the available data it should be noted that the reporting rate is close to the critical value that Cunningham and Olsen (2009) used to eliminate species from their analysis, so interpreting the fitted model needs caution. The fixed effects are zone and Year. As noted in Figure 5 the effect of year is not substantial.

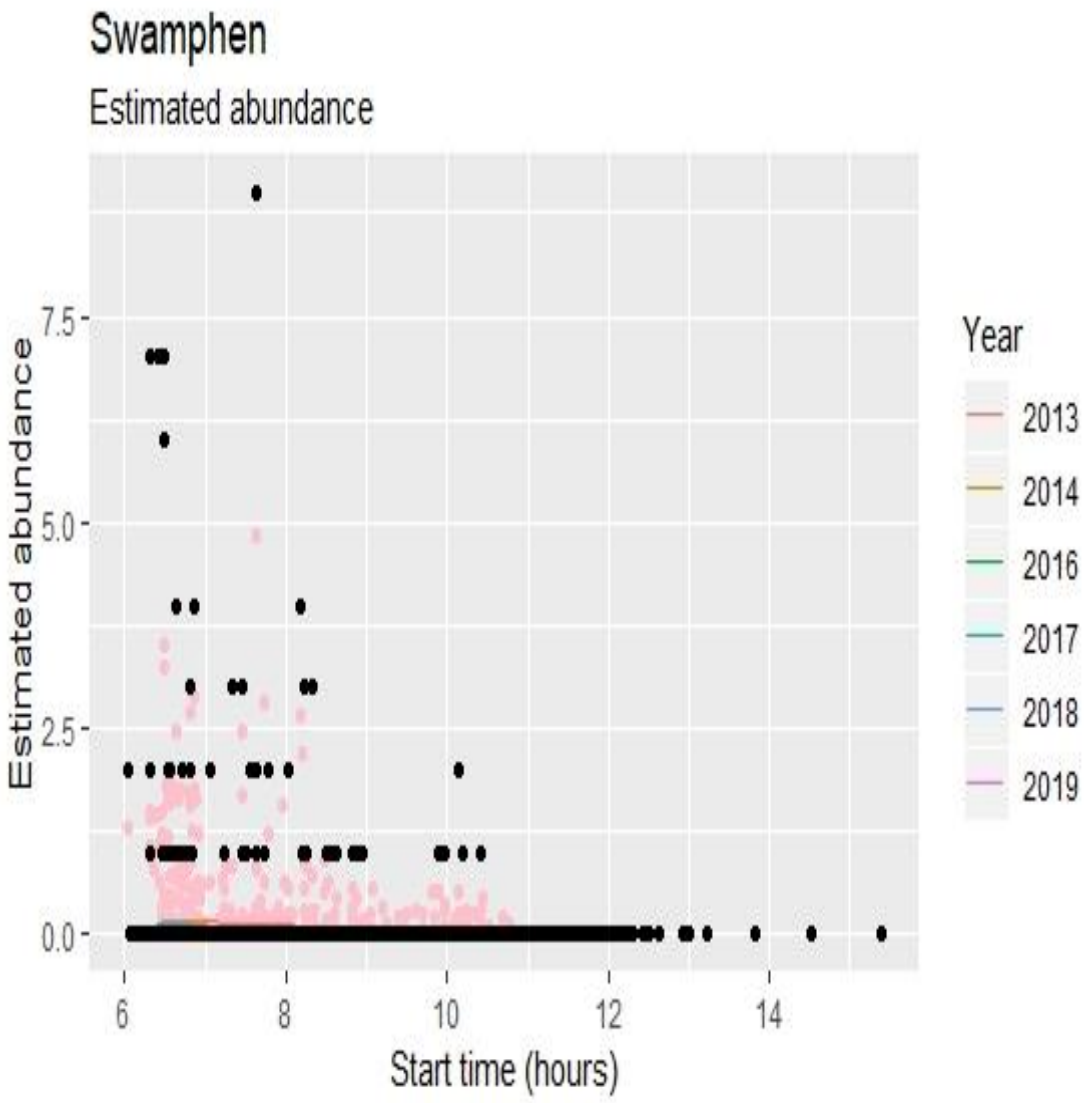


Figure 5. Estimated number of Swamphen observed as a function of count starting time. The observed counts are shown (black dots) and the estimated abundances accounting for the random effects (pink dots). The effect of start time is substantially hidden by the observed zeros.

Masked Lapwing

Fifty-eight records of Masked Lapwing have been made. The majority (54) were from open vegetation.

Emerald Dove

The fixed effects zone, vegetation and starting time were significant. The Emerald Dove is estimated to be very much more abundant in the forest vegetation groups and apparent abundance declines with increasing interval from sunrise (see Figure 7).

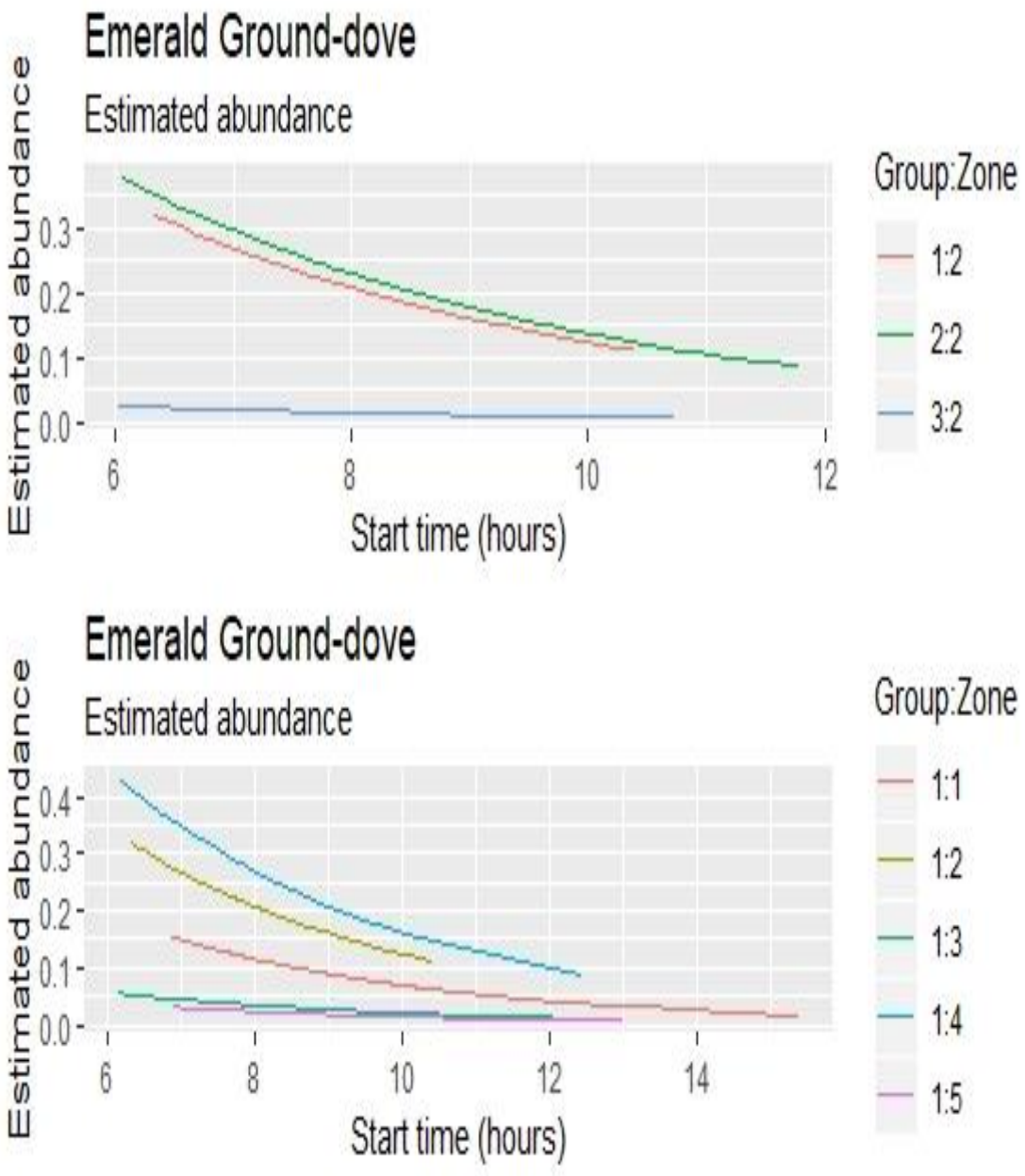


Figure 6. Estimated number of Emerald Dove as a function of count starting time and plot vegetation group and zone. The top graphic illustrates the impact of vegetation group within a zone (2) and bottom graphic illustrates the impact of zone within a vegetation group (1). The length of the lines reflects the variation in start times across the sites within zones and vegetation groups.

There was no year effect so no significant change in 2019.

Sacred Kingfisher

There was one significant fixed effect for this species, zone. The observed abundance per zone is plotted in Figure 7.

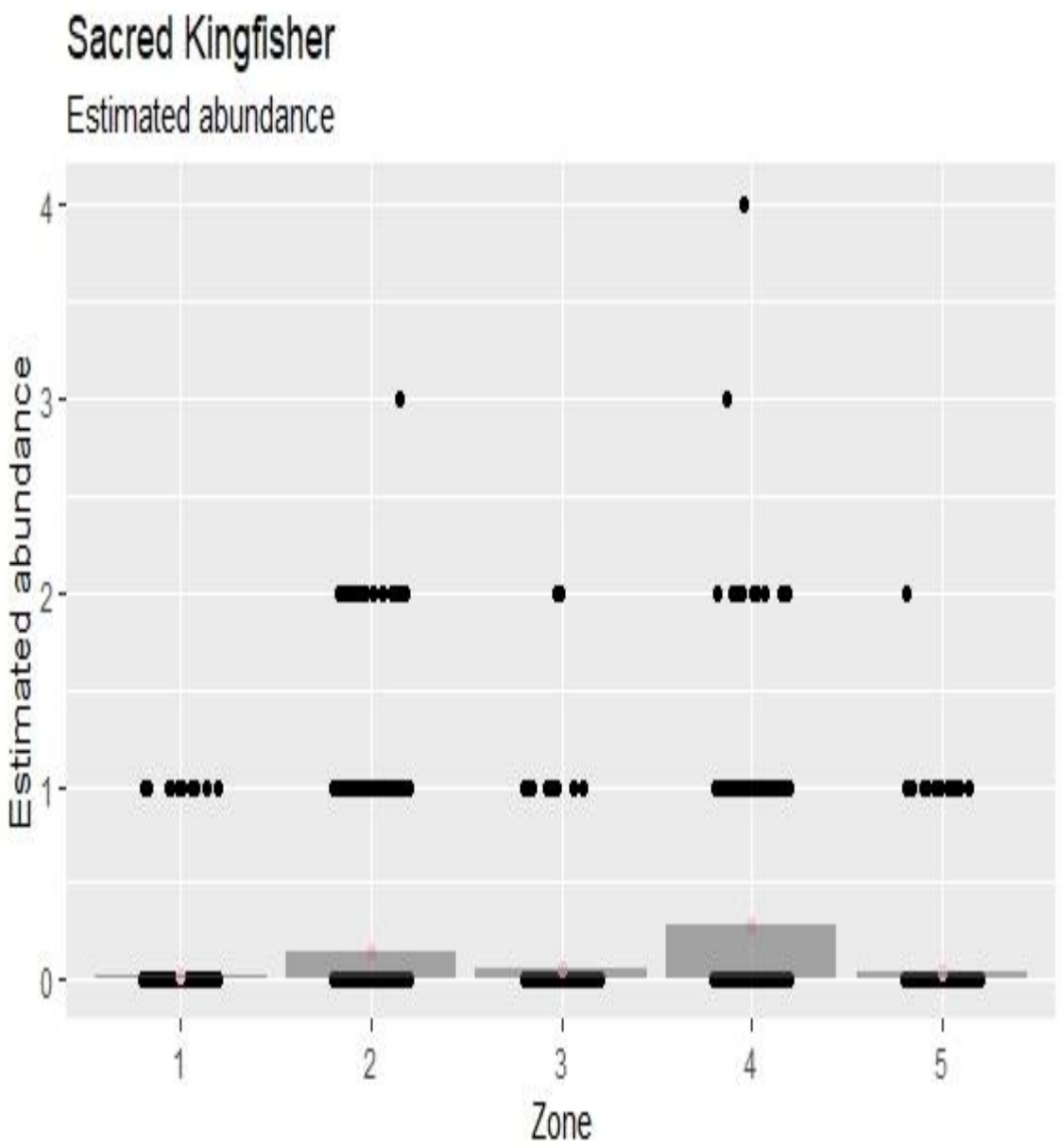


Figure 7. Estimated number of Sacred Kingfisher as a function of the zone of the plot observed. The Observed abundances are show (black dots).

There was no year effect so no significant change in 2019.

Pied Currawong

The best model for the Pied Currawong abundance was one with the factor Year as the single predictor. The observed and expected abundances are presented in Figure 8.

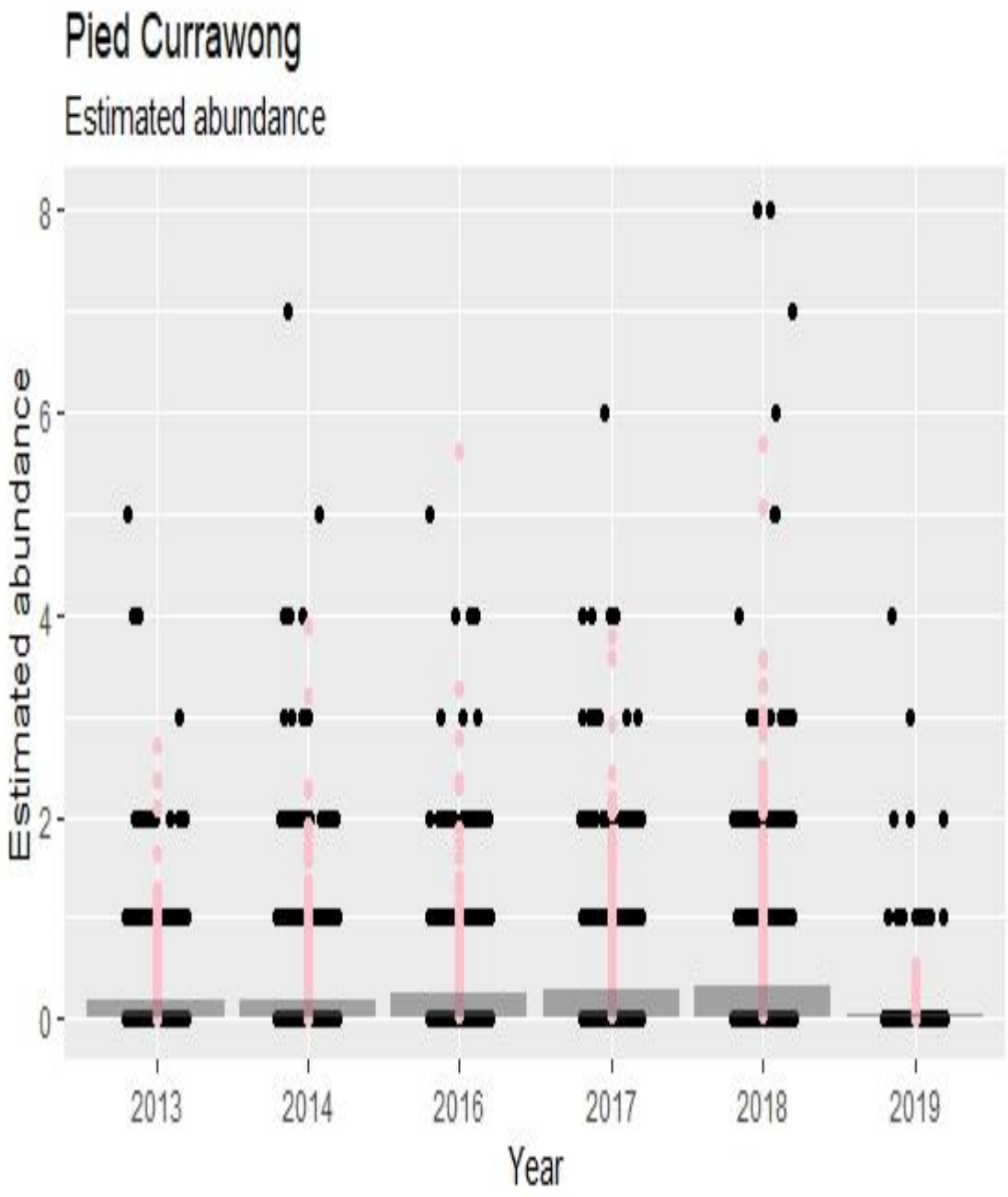


Figure 8 Estimated number of Pied Currawong as a function of the year of survey. The observed counts (black dots) and estimated abundances after accounting for the random effects (pink dots) are shown. Note the very much smaller abundances recorded for the year 2019.

There was a year effect with 2019 significantly lower than all previous surveys.

Golden Whistler

The fixed effect vegetation group is highly significant. The observed data and predicted abundance are show in Figure 9 as a function of the fixed effect vegetation group. Note that the observed data have been jittered to allow display.

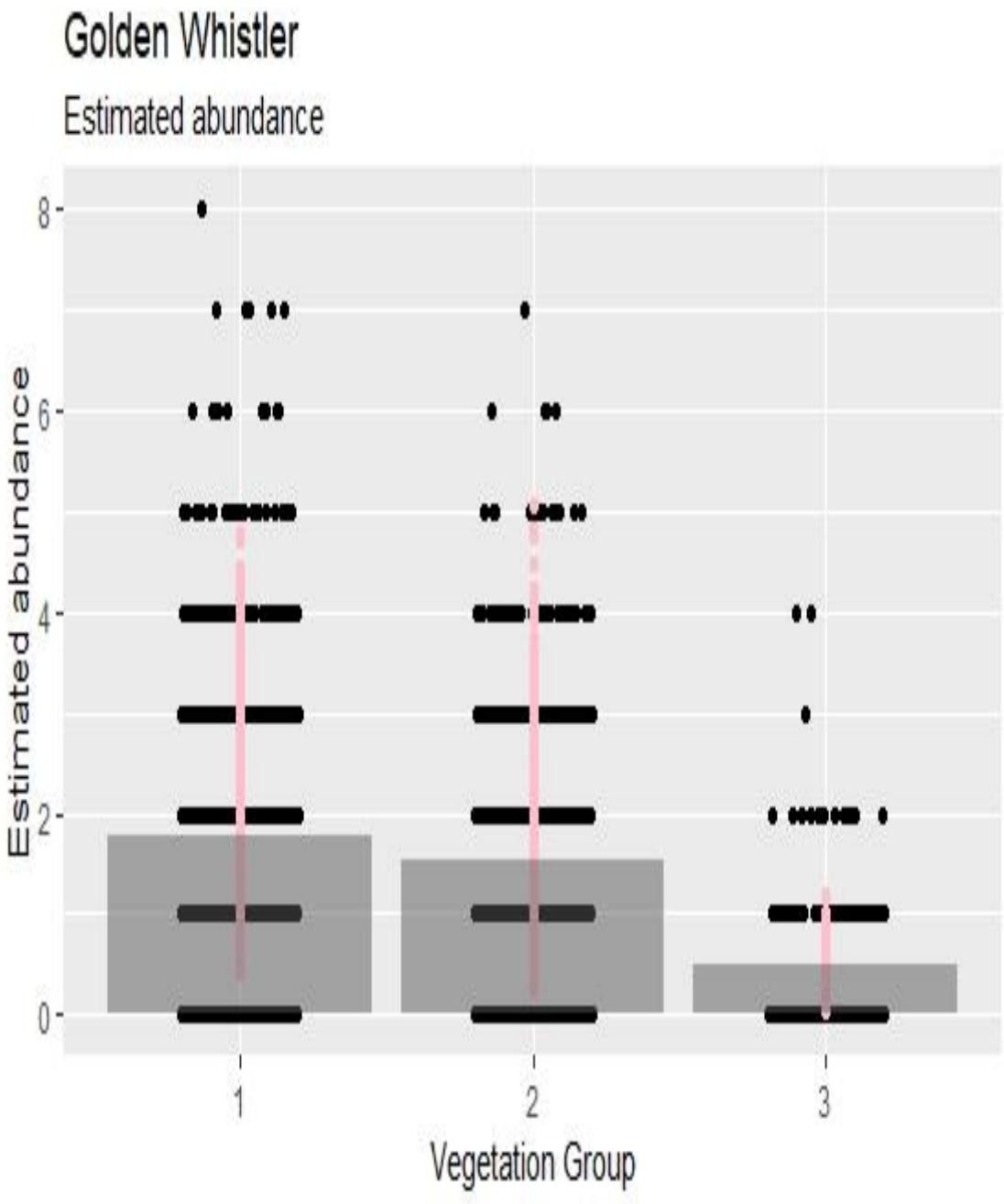


Figure 9. Estimated number of Golden Whistler as a function of vegetation group. The observed (black dots) and estimated (pink dots) after accounting for the random effects.

There was no year effect so 2019 was not significantly different to previous surveys.

Magpie-lark

The fixed effect zone is significant (see Figure 10). Note that only two zones have significant numbers of Magpie Lark.

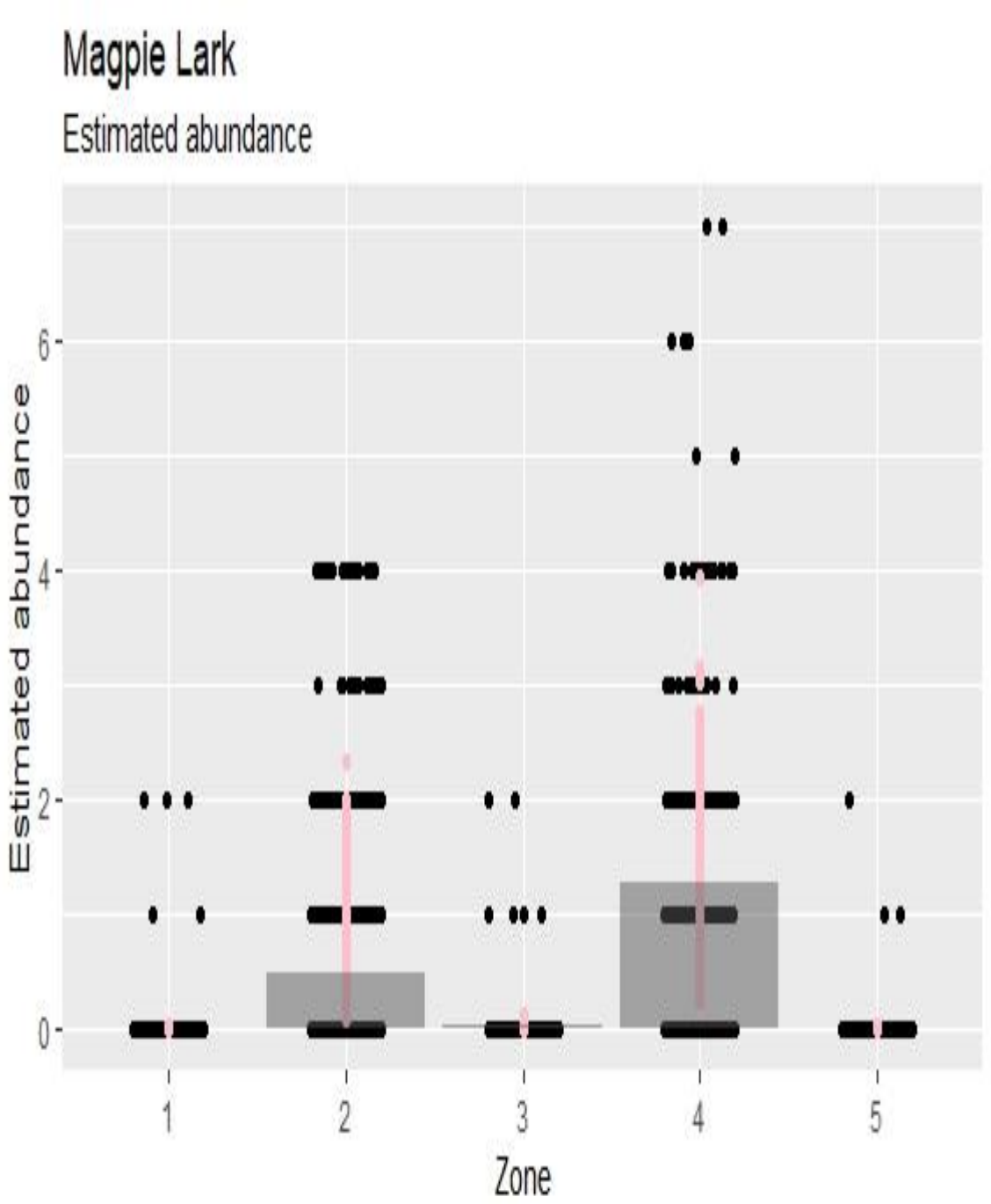


Figure 10. Estimated number of Magpie-lark as a function of zone. The observed abundances (black dots) and estimated abundances (pink dots) after accounting for the random effects are also shown.

There was no year effect so 2019 survey was not significantly different to previous surveys.

Welcome Swallow

The fixed effect vegetation group is significant (see Figure 11) with the open vegetation offering the greatest opportunity for this species to forage.

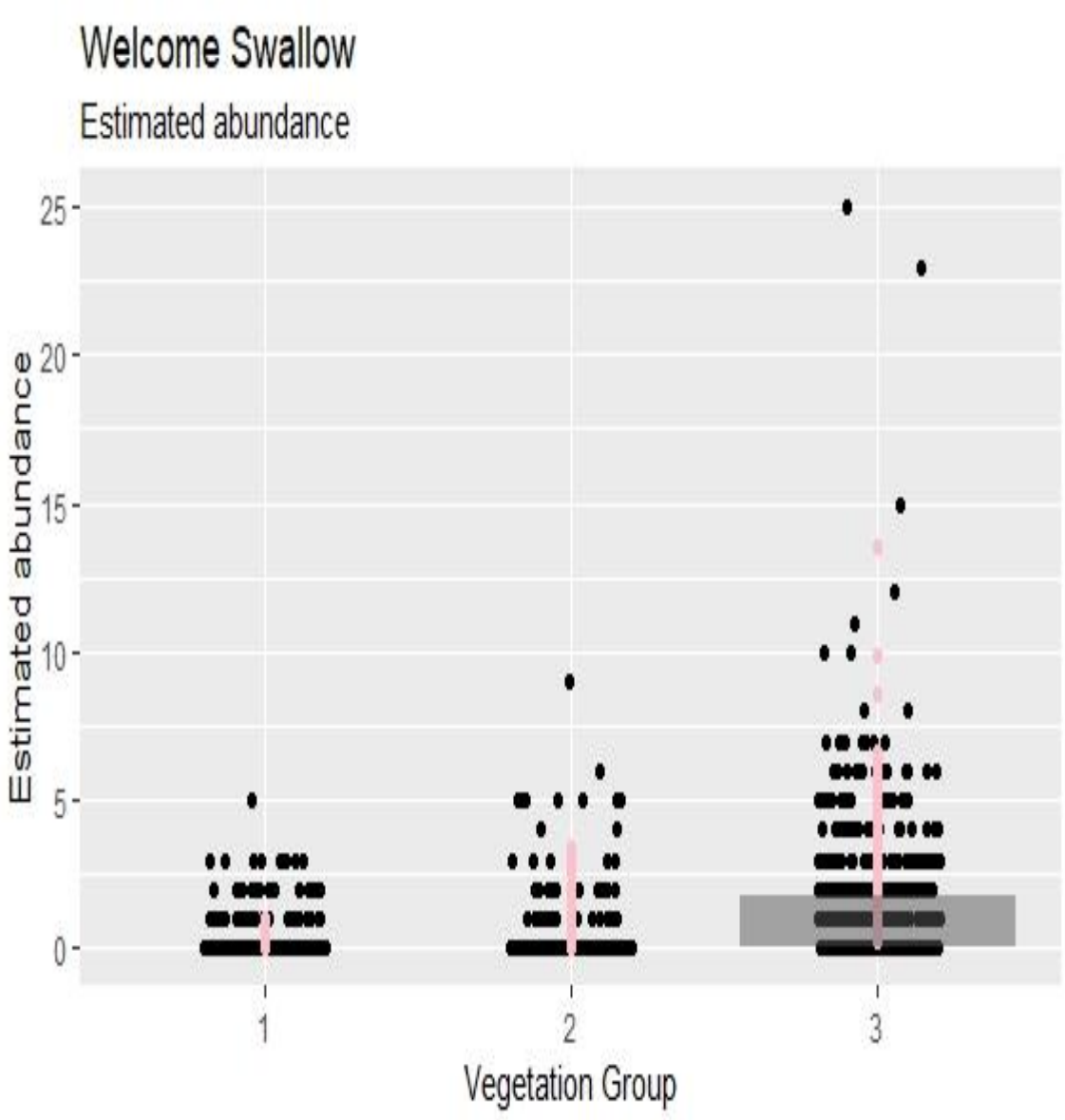


Figure 11. Estimated number of Welcome Swallow as a function of vegetation group. The observed abundances (black dots) and estimated abundances (pink dots) after accounting for the random effects are also shown.

There was no year effect so 2019 survey was not significantly different to previous surveys

Silvereye

Note that a different mixed model is fitted to the Silvereye data; due to the difficulty of recording abundance the data were converted to presence or absence. The fixed effect vegetation group was significant as were year of survey and the vegetations group. The probability of recording Silvereye in the forest is approximately three times that of recording it in open vegetation (see Figure 12, top graphic). While more difficult to detect the predicted probability of Silvereye is generally lower for zones 4 and 2 Figure 12, lower graphic).

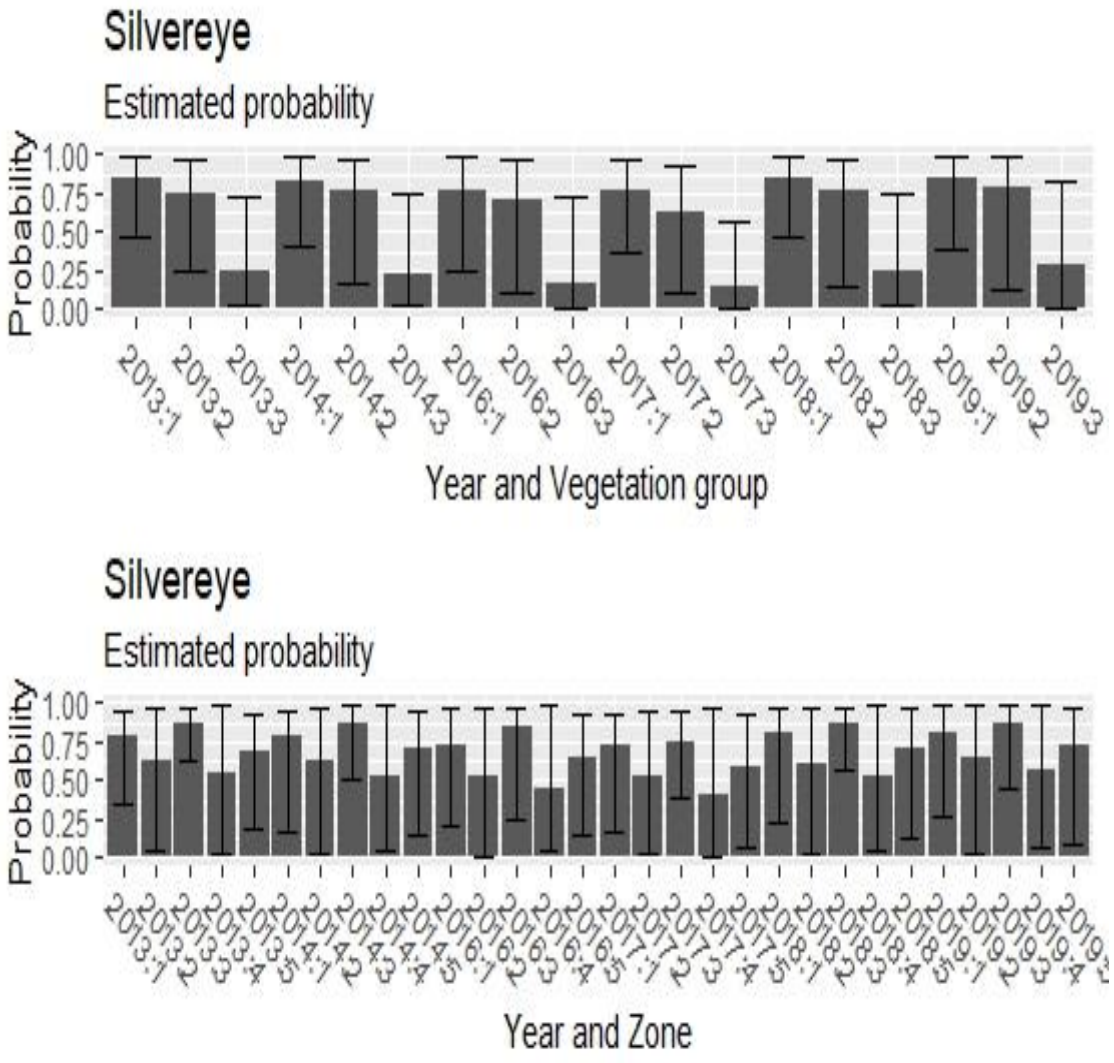


Figure 12. Probability of occurrence of Silvereye as a function of year of survey and plot vegetation group (upper graphic) and as a function of year of survey and zone of the plot (lower graphic).

There was a year effect with 2019 survey probability of recording less than the 2017 and 2018 surveys but not different to other surveys.

Blackbird

There was a significant fixed effect of zone, being larger in zone 2 relative to the others. (see Figure 13).

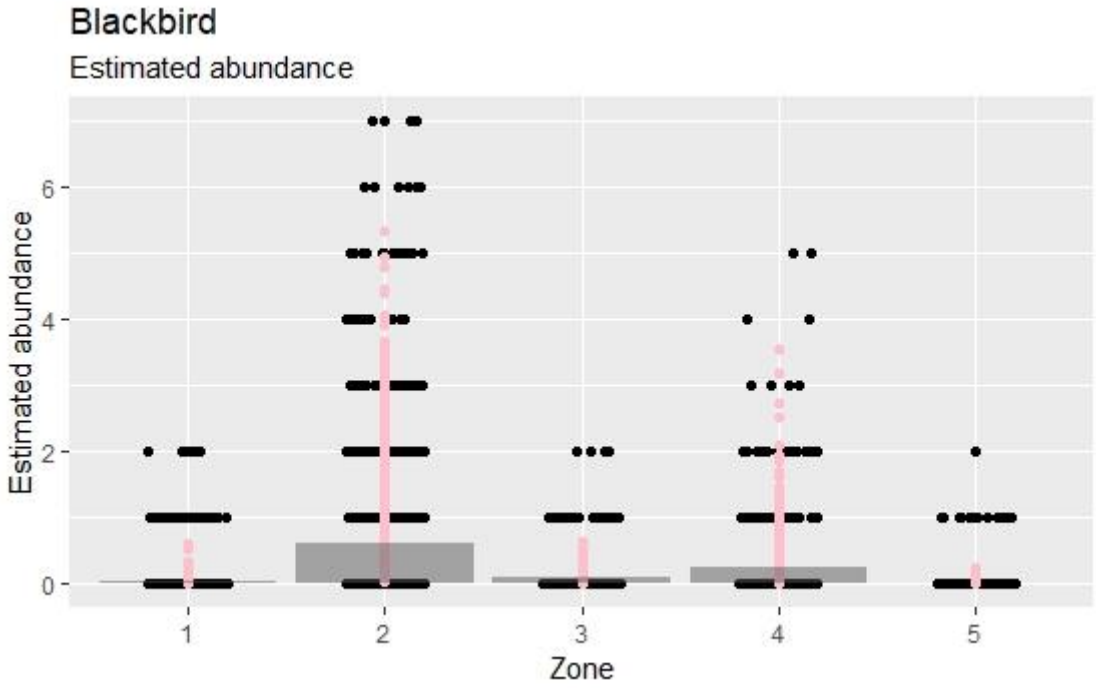


Figure 13. Estimated number of Blackbird observed as a function of the zone in which the plots exists.

There was no year effect so 2019 survey was not significantly different to previous surveys.

Song Thrush

Only 69 records of Song Thrush have been made from plot observations over all surveys (3.2%). Consequently no model has been fitted. The majority of these records (63) are from the Palm forest.

It is recognized that generalized linear mixed models can be difficult to fit even with well-designed and generally balanced surveys. In the present study the number of random effects contributes to the complexity of the models. The small number of individuals recorded at each plot also adds difficulties to the parameter estimation. For some species the estimated confidence intervals are clearly very wide and appear to be well outside the observed data. This reflects some of the complexities of these models. Even with the additional data from the sixth survey in 2019 some of these difficulties remain. The additional year's (2019) data has often confirmed the fact that for some species there is not a single best model based on the Akaike Information Criterion (AIC).

A Poisson distribution has been assumed for the error structure. This is a reasonable first approximation. Additional work may be needed to explore some alternative error structures and alternative random effects specifications.

In general, where the habitat influences are included in the models they appear to be sensible and generally reflect what we know about the biology of the species. In comparison to the previous reports, and with additional data, there is less potential difference between years than was noted for last year's report. Additional modelling may be necessary to clarify if this is a general result.

To allow for a statistical comparison of the survey data pre- and post-rodent eradication, fixed effects such as vegetation type and year of survey together with random effects such as plot, observer and day differences will need to be taken into account. The development of increasingly powerful software for fitting generalized linear mixed models is making the fitting of more complex models possible.

Species distribution

Figures 14–17 show the 2019 frequency distribution of 14 species across the lowlands of Lord Howe Island. These distribution maps are based on the relative occurrence of each species derived from the accumulated plot counts. Plot counts have been distributed within a grid pattern extending across the survey area (see Figure 1).

The size of each dot corresponds to the number of times each species is recorded as present within each grid cell. In each cell there are two count plots, giving a possible score of eight if the species is seen on every count in that cell. The smallest dot indicates one or two occurrences, with increasing dot size (doubling in size with each increment) for three or four and five or six occurrences. The largest dot indicates a maximum of seven or eight out of the possible eight counts. An adjusted score was used when fewer than eight counts were made in the cell.

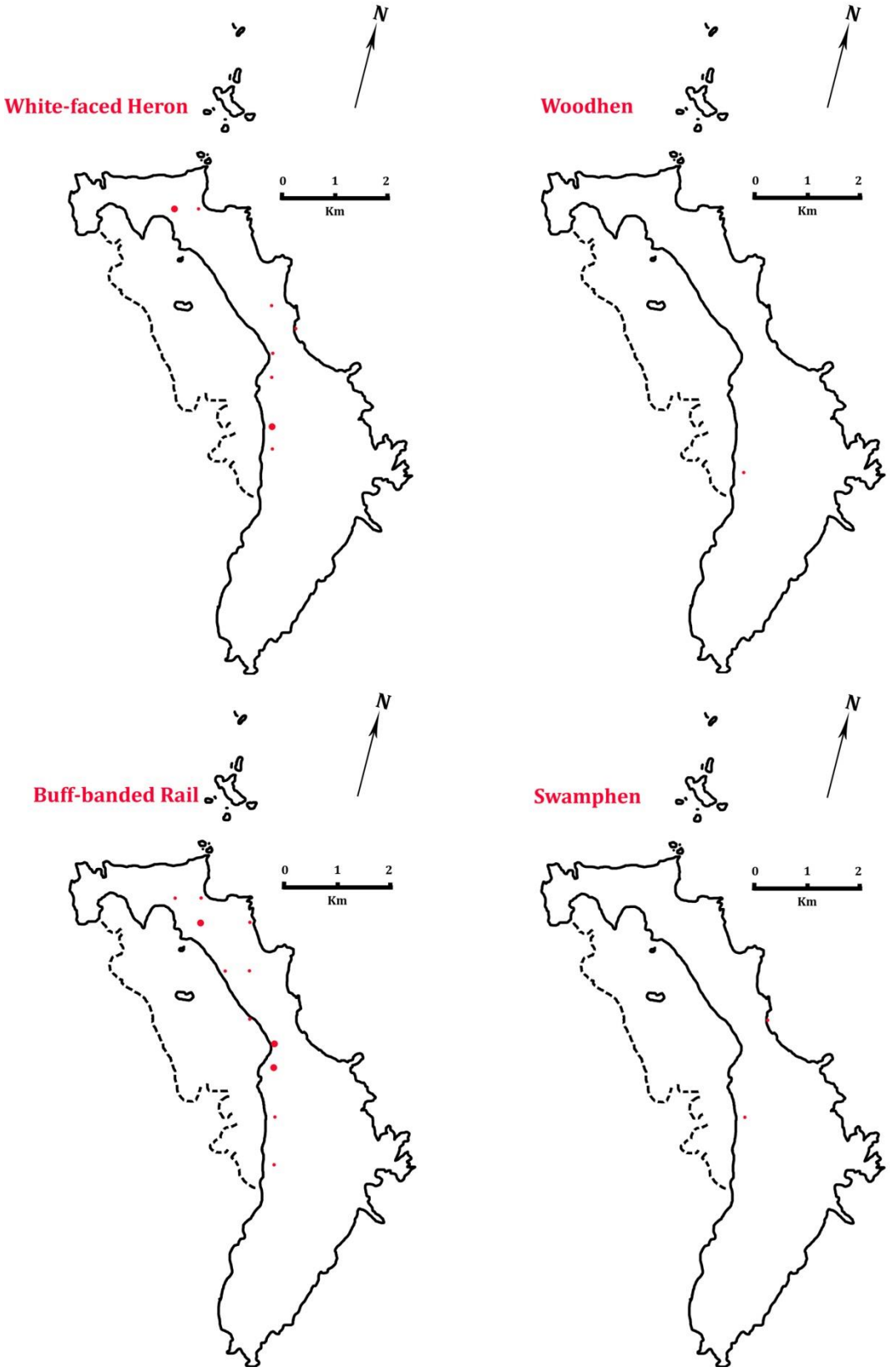


Figure 14. Distribution of White-faced Heron, Woodhen, Buff-banded Rail and Swamphen, September 2019, northern LHI, by frequency of occurrence at plots

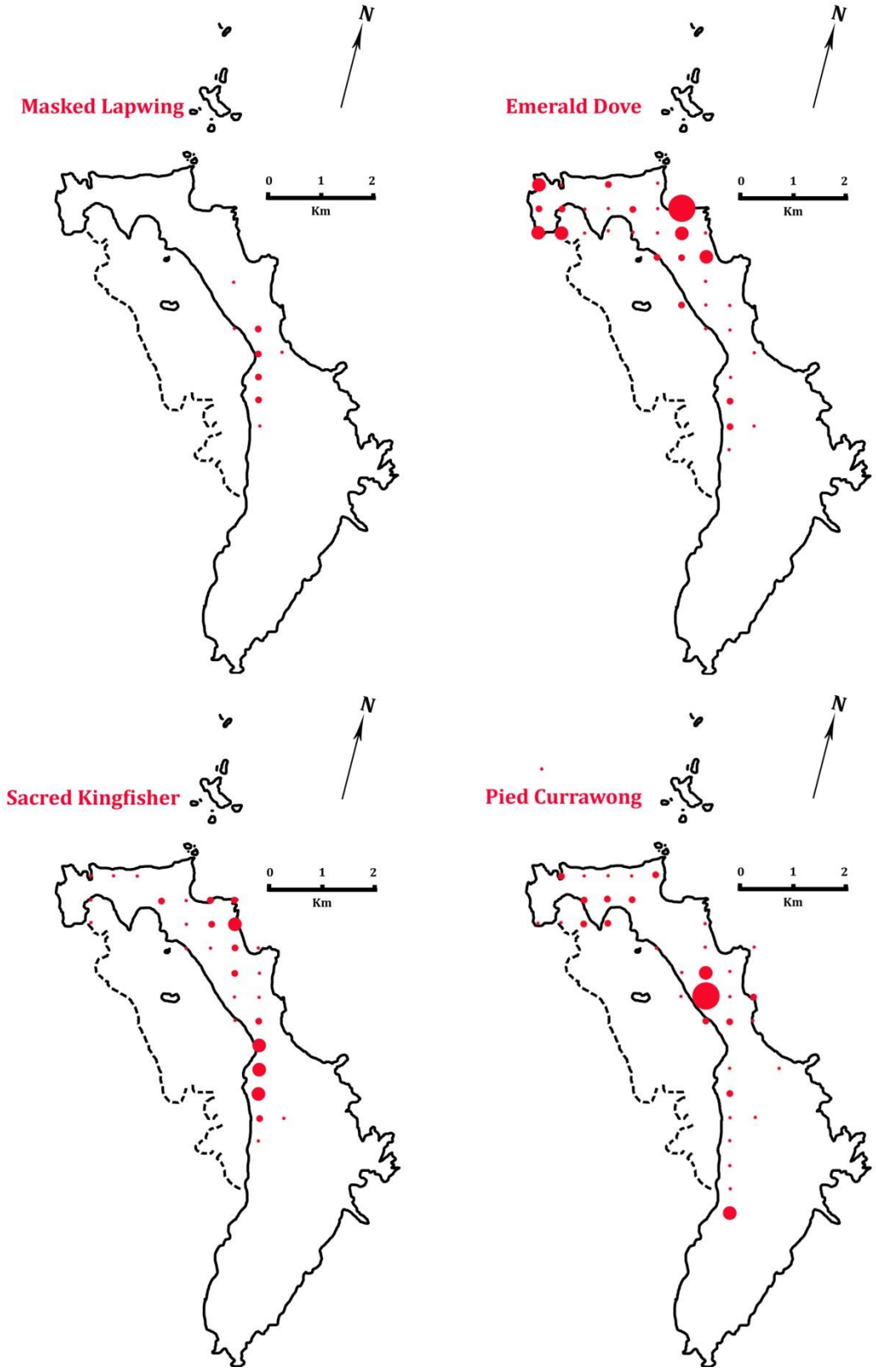


Figure 15. Distribution of Masked Lapwing, Emerald Dove, Sacred Kingfisher and Pied Currawong, September 2019, northern LHI, by frequency of occurrence at plots

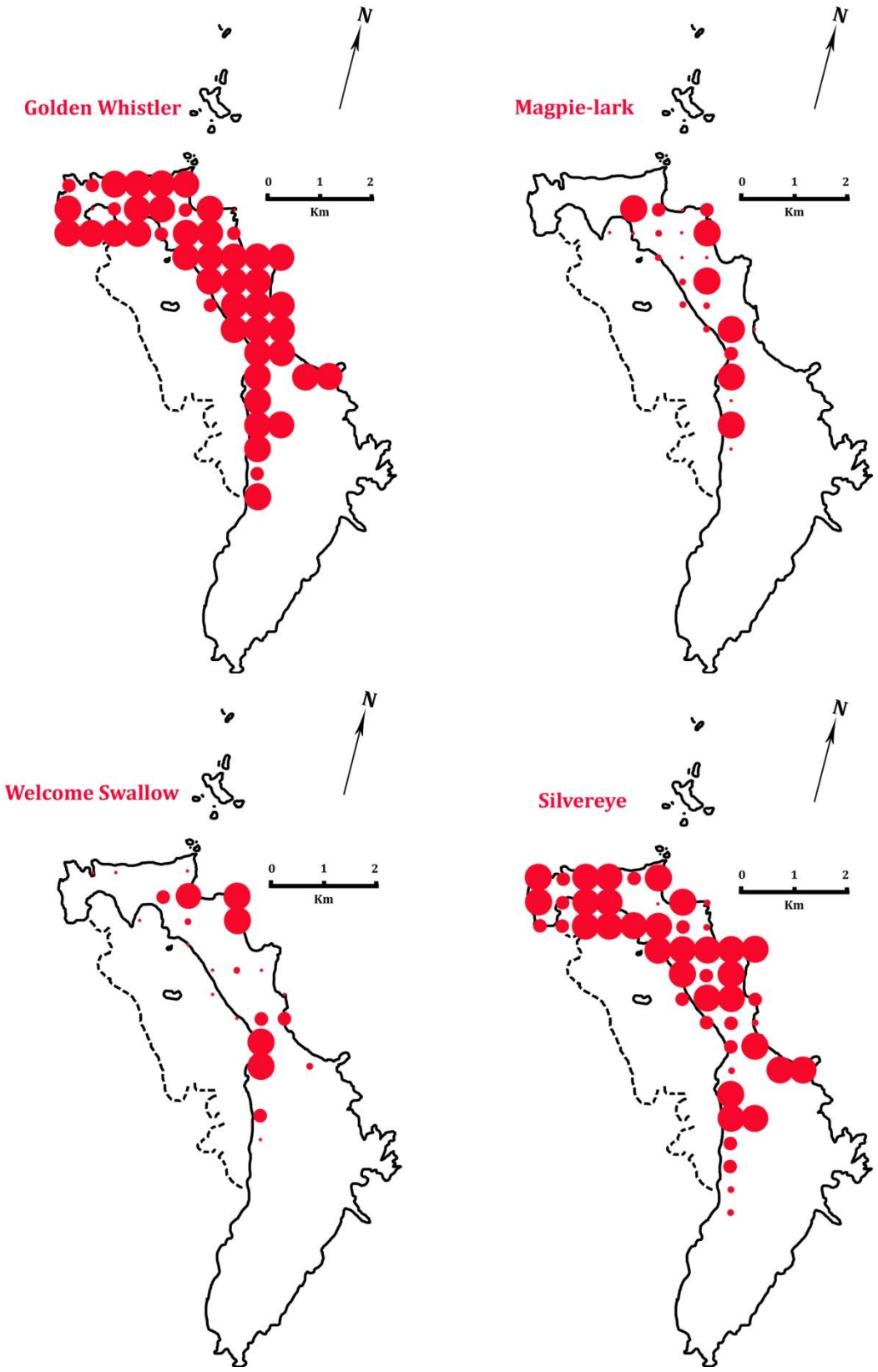


Figure 16. Distribution of Golden Whistler, Magpie-lark, Welcome Swallow and Silvereye, September 2019, northern LHI, by frequency of occurrence at plots

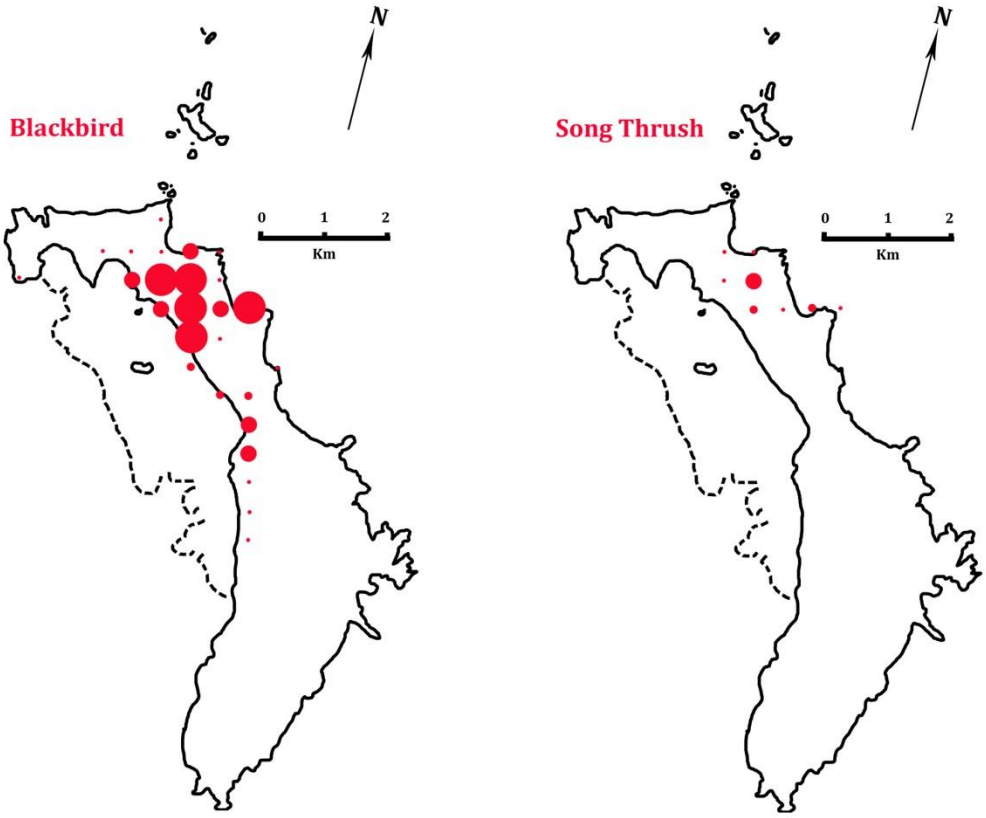


Figure 17. Distribution of Blackbird and Song Thrush, September 2019, northern LHI, by frequency of occurrence at plots

Transect counts

For all transect surveys conducted since 2013 the following species have been recorded; Woodhen, Buff-banded Rail, Emerald Dove, Sacred Kingfisher, Common Blackbird and Song Thrush. For the 2019 transect survey all species seen or heard along each transect were reported. The additional nine species and the mean number of individuals for each are shown in Table 6. These data are reproduced here in case it is decided to continue with transect surveys into the future.

Table 6. Mean number of nine additional species along seven transects in 2019.

Species name	Mean number of individuals
Masked Lapwing	1.33
Whimbrel	1.0
Feral Pigeon	1.0
Pied Currawong	1.38
Golden Whistler	4.39
Magpie-lark	2.23
Silvereye	7.68
Welcome Swallow	3.05
Common Starling	4.5

In six days, seven observers recorded 106 observations with an additional observer also surveying on these days in the opposite direction – resulting in a total of 90 counts for birds on these transects (see Table 1). The additional observer also counted on six mornings from shortly after sunrise following exactly the protocol of the standard evening transect (that is to say not in the reverse direction as that observer had done with evening counts). This gave another 12 counts of bird numbers to compare with evening counts. The speed of travel for all transect counts was standardized to 2 km/hr in 2014 and has been adhered to ever since.

In 2013, before standardization was applied, the average speed was 3.21 km/hr (range 1.94–4.47). In 2014, however, the average speed was 1.90 km/hr (range 1.54–2.16). Consequently, the variance in the speed of travel was significantly reduced (2013 variance 0.42, SD $\pm$ 0.64; 2014 variance 0.01, SD $\pm$ 0.11). The speed of travel in 2016, 2017, 2018 and 2019 was similar to that in 2014.

Woodhen

There is no evidence that direction is associated with the number of Woodhen recorded, but the combined data do suggest that the transect length and year are associated with the number of individuals recorded (see Figure 18). The observed data have been jittered to allow display. It appears that there has been a substantial increase in the number of Woodhen recorded in 2018 compared with 2017 but note that no Woodhen were recorded in 2019.

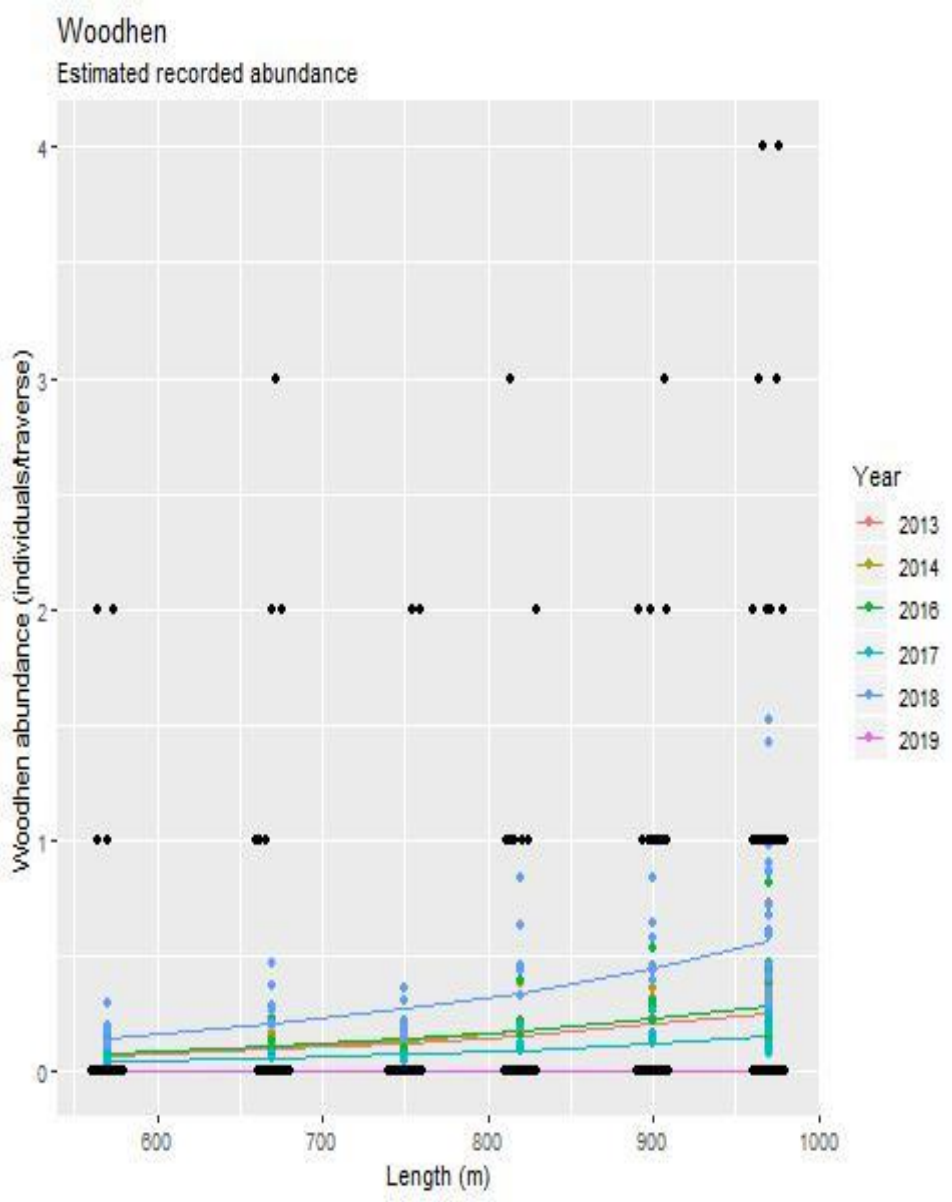


Figure 18. Observed number of Woodhen (black dots) and estimated abundance as a function of transect length with random effects (blue dots) and without random effects (coloured lines) in calculating the estimates.

Buff-banded Rail

In contrast to previous years there is limited support for more complex models for this species. The best model is one with year of survey and direction of travel as predictors, but the level of support is low (around 30%). Figure 19 shows the predicted values and estimates of the 95% confidence intervals, which are wide and in themselves would suggest that there is no difference between the years or travel however in contrast to previous years the number of Buff-banded Rail was very much lower in 2019.

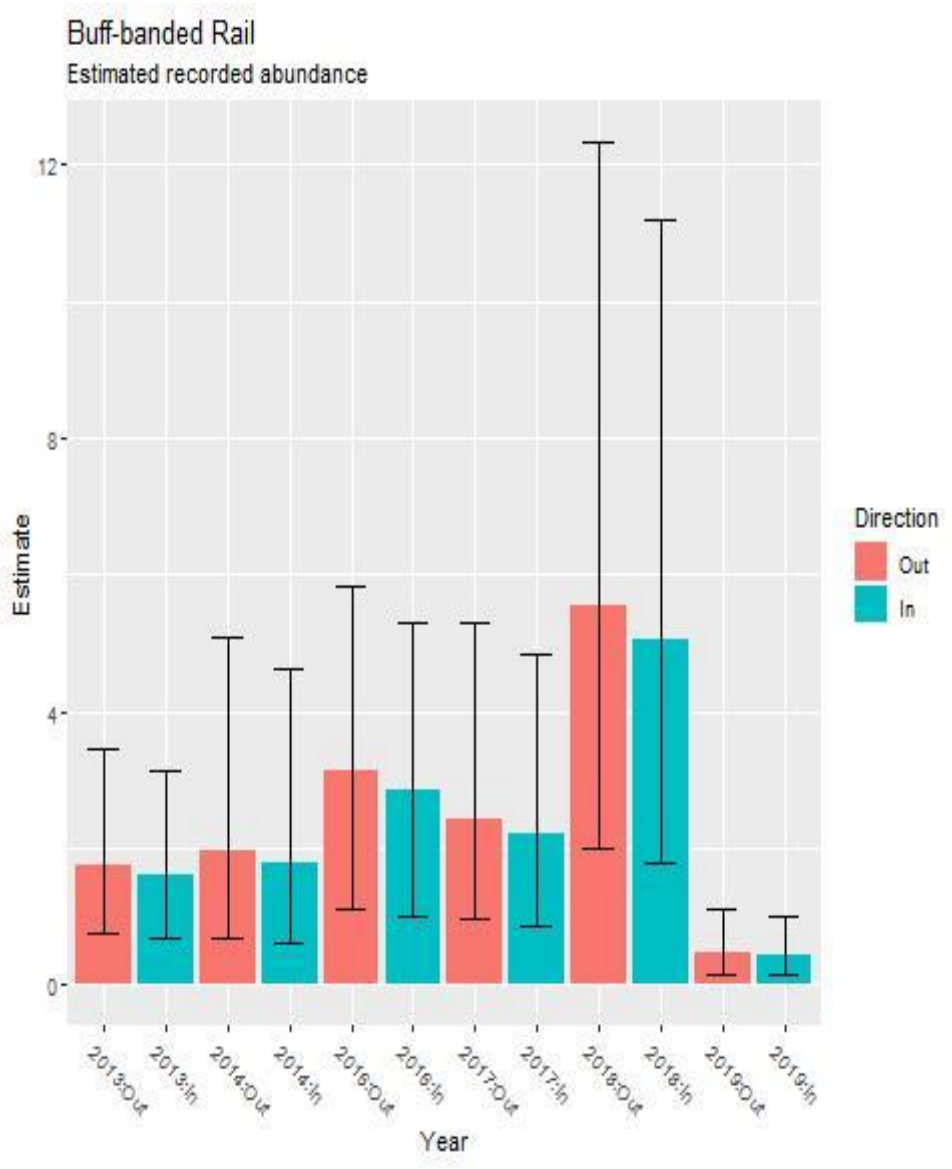


Figure 19. Estimated abundance of Buff-banded Rail as a function of survey year and direction of travel along transect together with estimates of 95% confidence intervals

There was a year effect with the 2019 survey significantly lower than previous surveys.

Emerald Dove

The fixed effects year and direction are significant. The return traverse (i.e. closer to sunset) yields approximately half the number of individuals compared to the outward traverse (see Figure 20).

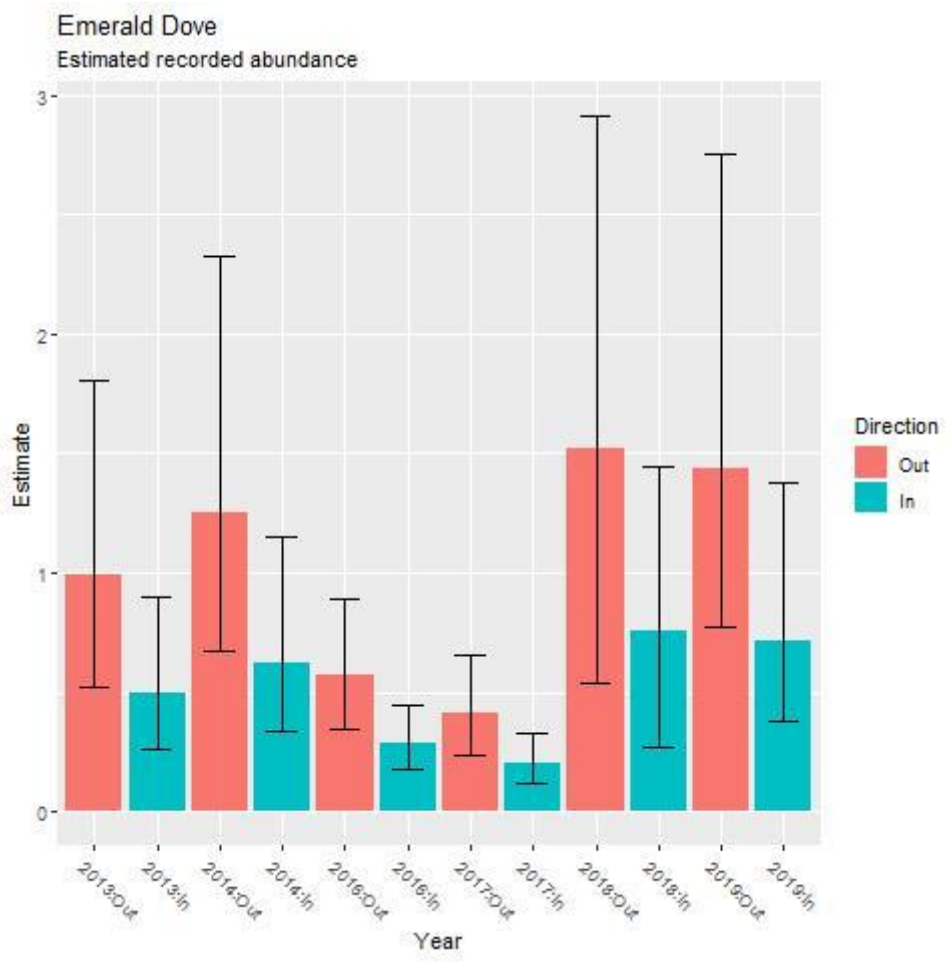


Figure 20. Estimated abundance of Emerald Dove as a function of survey year and direction of travel along transect together with estimates of 95% confidence intervals

There was no year effect so no significant difference in 2019. Note the large increase in 2018 relative to that observed in 2016 and 2017 which was sustained in 2019.

Sacred Kingfisher

There is evidence that year has an effect on the number of individuals observed and in contrast to earlier years the direction of travel is also important. It appears that the number of Sacred Kingfisher have continued to increase from the low seen in first survey in 2013 (see Figure 21). Note that as in 2018 there is a model that contains the transect length as a predictor that has equal support as the model without transect length. To facilitate comparison with the 2018 report the model without transect length is presented here.

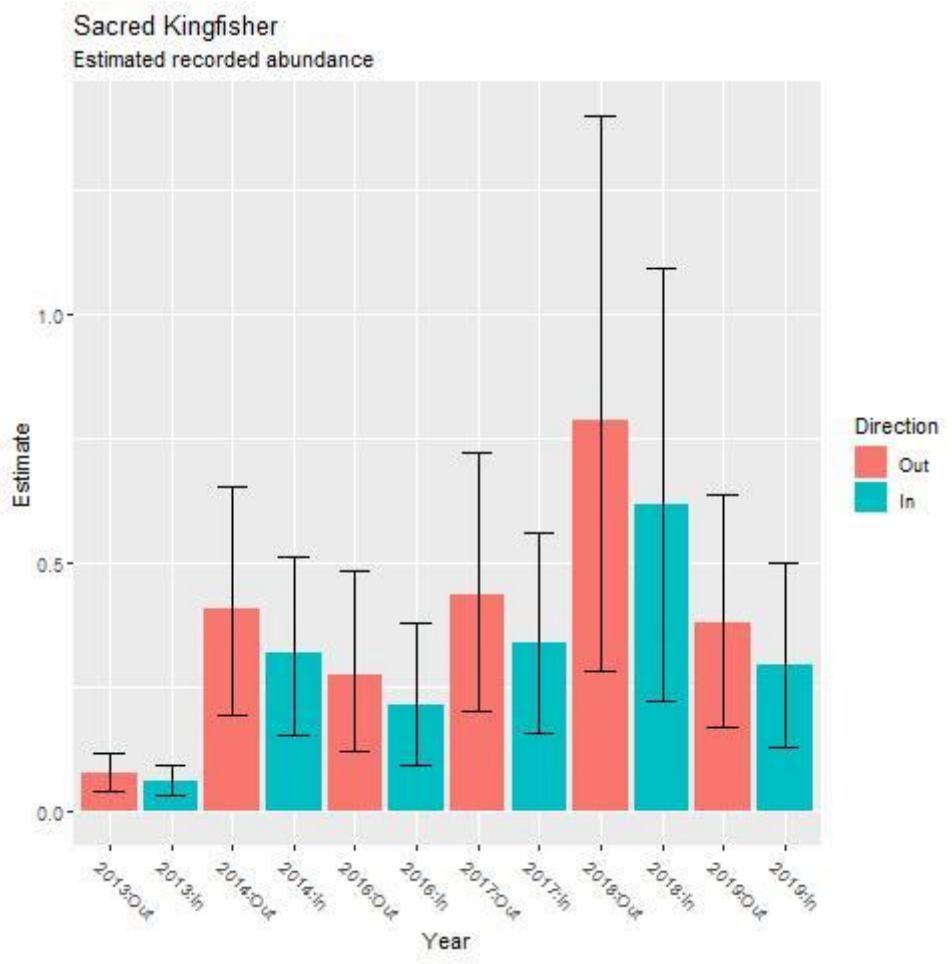


Figure 21. Estimated number of Sacred Kingfisher as a function of survey year and direction of travel together with estimates of 95% confidence intervals.

There was no year effect so no significant change for 2019.

Blackbird

There are significant differences in the observed abundances due to the direction of travel and the year of survey. The direction of travel is undoubtedly due to the return traverse being closer to sunset and the birds settling into their roosts. The differences between years are not strong. The confidence intervals suggest that the differences are not important in contrast to the AIC ranking of the candidate models which suggests that the differences between years may be real (see Figure 22). Compared to 2018 the number of Blackbird per transect is lower in 2019 but not necessarily lower than the early years.

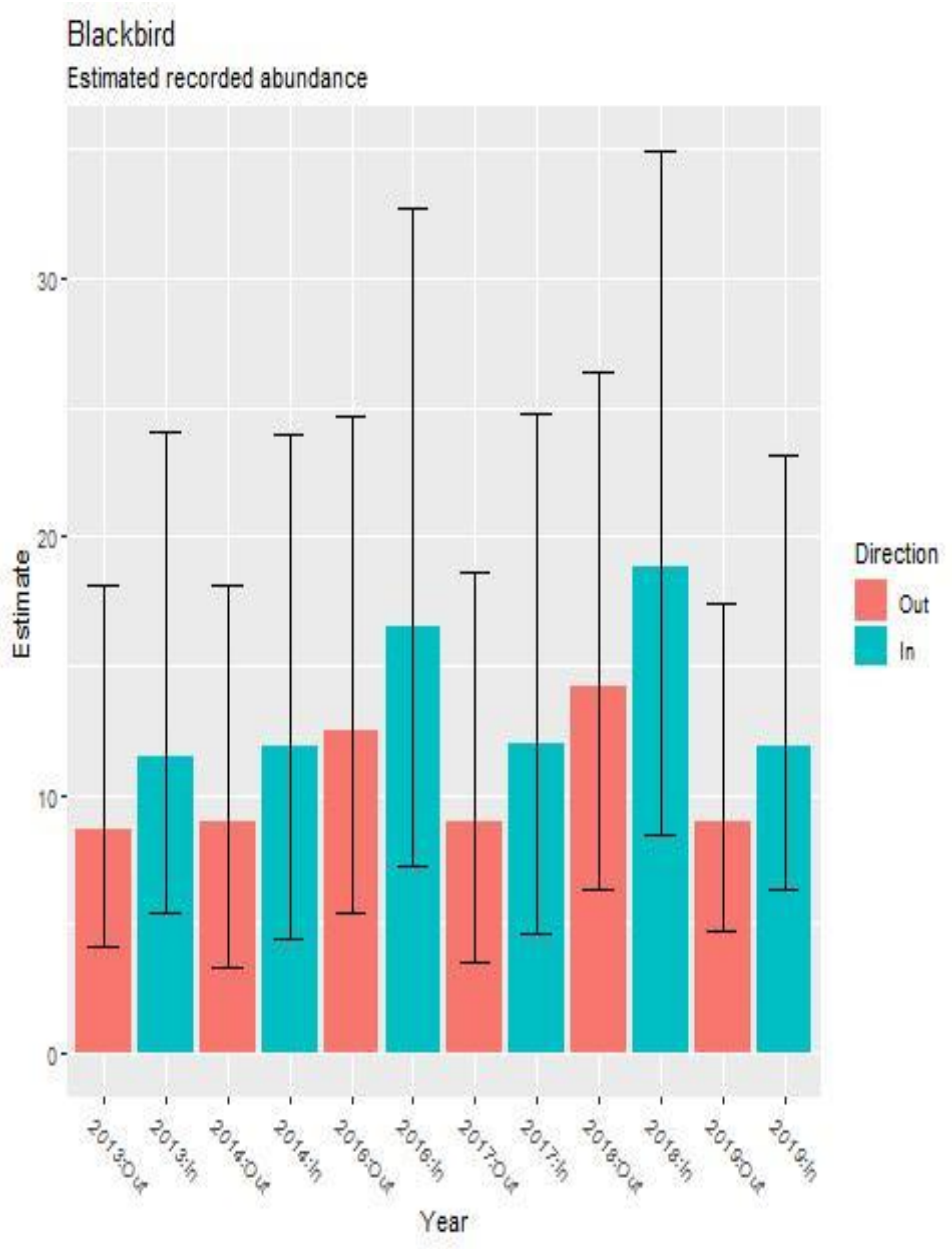


Figure 22. Estimated number of Blackbird as a function of survey year and direction of travel along transect together with estimates of 95% confidence intervals

There was no year effect so 2019 not significantly different to previous years.

Song Thrush

With more data the complexity of the best model has increased from one with length of transect to having different intercepts for year of survey and direction of travel (Figure 23). This figure also shows the observed data and the estimated abundances that incorporates the random effects within the model. The observed data points have been jittered to allow display. This more complex model was again the most supported with the addition of the 2019 data.

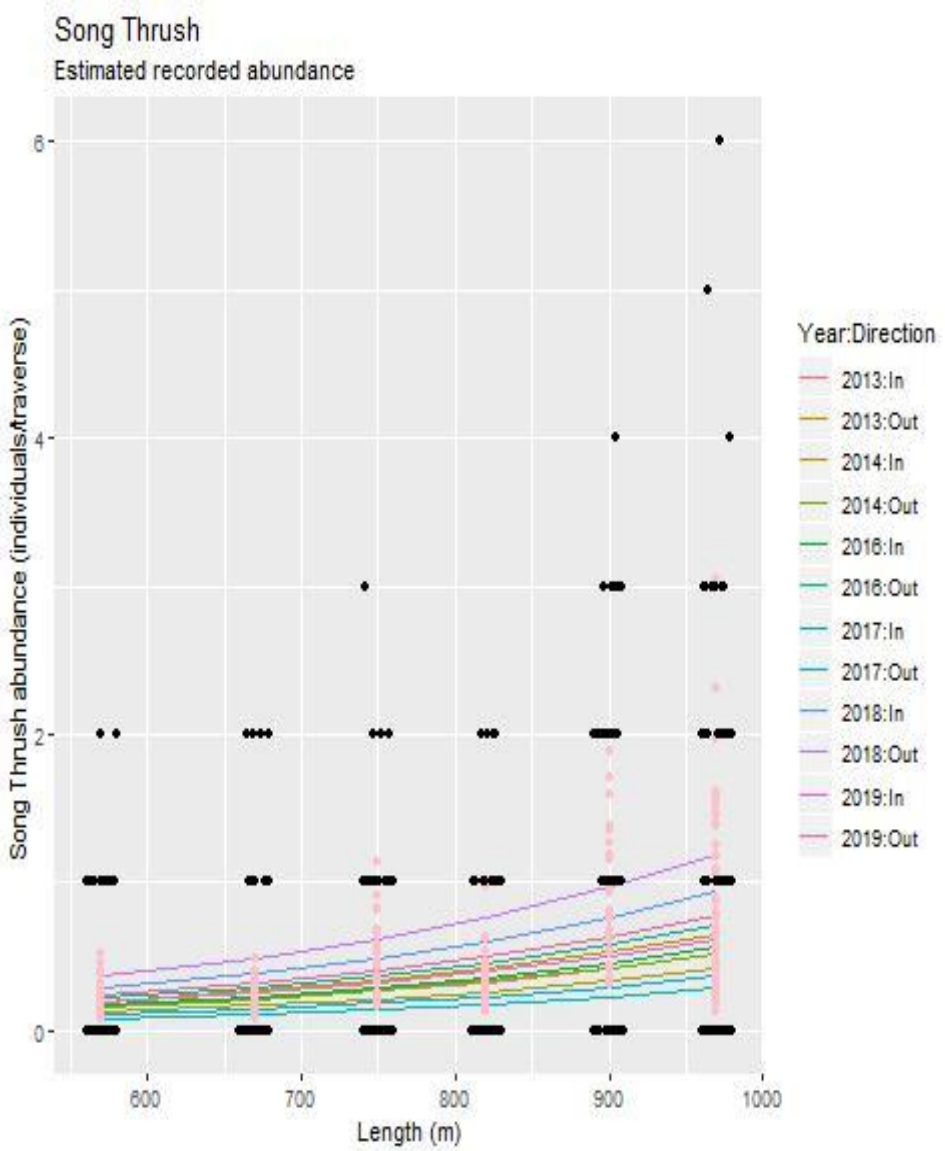


Figure 23. Observed Song Thrush abundance (black dots) and estimated abundance as a function of transect length, with random effects (pink dots) and colour coded lines for the year of survey and direction of travel

There were small year effects; it did not appear that the 2019 counts were substantially lower than other years.

One of the important reasons for monitoring landbird populations before the rodent eradication project was to establish some background estimates of selected avian species abundances. We now have five surveys spread over the period 2013 to 2018.

In four of the six species (Emerald Dove, Sacred Kingfisher, Song Thrush and Woodhen) there is now evidence of differences between the years of survey and the models suggest that the current survey effort is able to detect changes over time. The interpretation of the apparent influence of the direction of travel along the transects needs further analysis but would appear to be driven by the period of the traverse relative to sunset. Emerald Dove and Sacred Kingfisher abundances are significantly higher for the outward traverse compared to the return count. This is in contrast to the Blackbird where the return count consistently yields a larger number of individuals recorded.

It would be easy to attribute the observed apparent influence of transect length to be a reflection of survey effort. Longer transects yield more individuals than shorter transects; we suspect, however, that the transect locations may also be of importance. This may be worth further exploration but certainly highlights the need to maintain the existing survey protocol in the years post the rodent eradication project.

The dense vegetation over much of the island makes it difficult to see and hence record the abundance of many bird species. Many observations are therefore based on assessing bird presence through their vocalizations, whether these be calls or song. Vocalizations can vary with the season and time of day. Although the breeding season can vary slightly from year to year, we are unable to allow for this variation, which may account for some of the small changes in the summary indices from survey to survey. However, we survey at the same time each year.

Discussion

The September 2019 survey started on 10 September; that is just under 9 weeks after the aerial baiting finished with some hand baiting still occurring during the bird survey period. Casual observations during the 2019 survey period indicated that for some species there was an early start to the breeding season but despite this there had been no time between the end of the rodent eradication project and the COG surveys for breeding to have increased observed population numbers and so influence any recovery from poison effects on non-target species.

Before the start of the aerial and hand-baiting project there were changes on the island that may have caused some bird species to increase. Whether this caused an early start to the breeding season is unknown. With the removal of chickens and the large reduction in the number of cattle some food resources such as grain could have possibly effected numbers of seed-eating bird species on the island. At the same time the reduced cattle numbers left many areas ungrazed and this could have affected the numbers of some bird species. It is

therefore possible that any changes reported in bird numbers may have little to do with the direct effects of the poisoning but rather to do with pre-baiting activities. Any direct consequences of the rodent eradication project can only be assessed after any input to populations caused by the 2019-20 breeding season has occurred.

When comparing population abundance between 2018 and 2019 for the plot surveys there appears to have been a decrease in Golden Whistler, Common Blackbird, Magpie-lark, Welcome Swallow, Sacred Kingfisher, Emerald Dove, Buff-banded Rail and Masked Lapwing but when compared with all previous surveys the year effect for 2019 of a decrease in numbers still holds for the Buff-banded Rail. Woodhen and Pied Currawong are not considered in this analysis because they were largely in captivity during our survey.

For the transect surveys, which are concentrated in the Settlement (hand-baiting) area, the Buff-banded Rail showed a year effect. Again, Woodhen is not considered because most were in captivity at the time of the survey nor is Pied Currawong because it was not a species included in earlier transect surveys.

Overall the distribution maps do not show any marked changes bearing in mind variation between years and for many species the small numbers involved. When comparing 2019 with previous surveys there is a marked change in the distributions of the Woodhen and the Pied Currawong and this is to be expected given the large number of individuals removed from the wild and into captivity. For the Pied Currawong, an inspection of the 2019 distribution map indicates wild birds concentrating near the captive aviaries.

The long-term aim of the bird surveys on Lord Howe Island was to document the effects of rodent eradication on the bird communities on the island. The effects of using poison distributed aerially and by hand and through bait stations may have had a direct impact on some non-target species such as the Buff-banded Rail but their possible subsequent recovery and the release of the captive Woodhens and Pied Currawongs cannot yet be assessed. In addition, the short time frame between poisoning and the bird survey has not allowed any assessment on possible long-term effects on non-target species. With the probability of eradicating rodents the increased food resources and possible increased inter-play between species may well lead to population increases for some species and not others. It is for these reasons that to obtain a picture of the long-term effects in the bird populations it will be necessary to repeat the surveys in 2020 and again in 2021.

Acknowledgements

The survey was conducted under an arrangement between the Lord Howe Island Board and the Canberra Ornithologists Group. The report was compiled by Peter Fullagar and Chris Davey with statistical input from A O Nicholls. With his intimate knowledge of the flora and fauna of the island, Ian Hutton was responsible for the arrangements and logistical support on the island and he provided invaluable input. The survey teams consisted of John

Brannan, Chris Davey, Don Fletcher, Peter Fullagar, Ian Hutton, Gail Neumann, Harvey Perkins, Michael Robbins and Alison Rowell. All, apart from Ian Hutton, are members of the Canberra Ornithologists Group.

We thank Nicholas Carlile from the Office of Environment and Heritage, NSW Department of Premier and Cabinet, and the Lord Howe Island Board for their support.

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APPENDIXES

Appendix A. Vegetation and habitat classifications of all 96 surveyed plots, LHI, 2019

Vegetation type	*Vegetation code*	*Vegetation group*	*No. of plots*
Drypetes australasica/Cryptocarya triplinervis	1	1	42
Drypetes australasica/Cryptocarya triplinervis (calcarenite variant)[1]	2	1	1
Drypetes australasica/Cryptocarya triplinervis (exposed variant)[1]	3	1	7
Cassinia tenuifolia-Poa poiformis	4	1	2
Howea forsteriana	5	2	22
Pasture	6	3	14
Dune	7	3	2
Golf course	8	3	2
Syzygium fullagarii[2]	9	2	2
Pasture/*Howea forsteriana*	10	2	2

Notes:

1. Calcarenite and exposed variants are treated as one type, giving a total of four paired plots
2. Name changed in this report from *Cleistocalyx fullageri* to *Syzygium fullagarii* (see Craven, 1998)

Habitat zones	*Habitat zone code*	*No. of plots*
North Hills	1	28
Settlement	2	28
Transit Hill	3	11
Suburban	4	12
South Hills	5	17

Appendix B. Geolocation, vegetation code, vegetation group, habitat zone and number of counts for all 96 surveyed plots, LHI, 2019

	Geolocation		*Vegetation*	*Vegetation*	*Habitat*	*No. of*
Plot number	*Latitude*	*Longitude*	*code*	*group*	*zone*	*counts*
1	31 31 09.2	159 02 27.8	1	1	1	4
2	31 31 06.7	159 02 25.2	1	1	1	4
3	31 31 16.8	159 02 31.0	1	1	1	4
4	31 31 12.8	159 02 31.0	1	1	1	4
5	31 31 05.8	159 02 21.4	1	1	1	4
6	31 31 04.3	159 02 24.7	1	1	1	4
7	31 31 00.4	159 02 24.8	4	1	1	4
8	31 30 56.9	159 02 23.0	4	1	1	4
9	31 31 01.2	159 02 31.7	5	2	1	4
10	31 31 00.3	159 02 37.3	5	2	1	4
11	31 30 57.4	159 02 39.8	1	1	1	4
12	31 30 54.7	159 02 37.3	1	1	1	4
13	31 30 56.1	159 02 56.5	1	1	1	4
14	31 30 52.9	159 02 57.7	1	1	1	4
15	31 30 52.2	159 03 04.4	1	1	1	4
16	31 30 50.1	159 03 01.6	1	1	1	3
17	31 30 58.3	159 03 05.2	1	1	1	4
18	31 31 02.9	159 03 09.0	1	1	1	4
19	31 31 00.1	159 02 52.7	1	1	1	4
20	31 31 02.4	159 02 55.7	1	1	1	4
21	31 31 02.0	159 03 03.4	1	1	1	4
22	31 30 59.3	159 03 01.0	1	1	1	4
23	31 31 08.1	159 03 11.3	3	1	1	4
24	31 31 11.0	159 03 09.1	3	1	1	4
25	31 30 49.1	159 03 21.5	1	1	1	4
26	31 30 49.3	159 03 25.8	1	1	1	4
27	31 30 52.9	159 03 39.6	3	1	1	4
28	31 30 49.6	159 03 39.7	3	1	1	4
29	31 31 08.1	159 03 46.4	6	3	2	4
30	31 31 10.9	159 03 44.0	6	3	2	4
31	31 31 06.0	159 03 34.4	6	3	2	4
32	31 31 05.8	159 03 30.4	6	3	2	4
33	31 31 15.7	159 03 29.5	5	2	2	4
34	31 31 18.7	159 03 30.1	5	2	2	4
35	31 31 23.8	159 03 44.6	5	2	2	4
36	31 31 21.3	159 03 47.0	5	2	2	4
37	31 31 09.8	159 04 04.7	1	1	2	4
38	31 31 07.1	159 04 09.1	1	1	2	4
39	31 31 08.9	159 04 19.2	10	2	2	4
40	31 31 12.1	159 04 16.3	10	2	2	4

41	31 31 17.1	159 04 18.9	6	3	2	4
42	31 31 21.3	159 04 18.9	6	3	2	4
43	31 31 19.1	159 04 01.0	5	2	2	4
44	31 31 22.4	159 03 59.4	5	2	2	4
45	31 31 29.0	159 04 06.3	5	2	2	4
46	31 31 32.2	159 04 10.4	5	2	2	4
47	31 31 33.6	159 03 51.2	5	2	2	4
48	31 31 28.1	159 03 50.3	5	2	2	4
49	31 31 32.1	159 04 21.7	5	2	2	4
50	31 31 35.6	159 04 23.8	5	2	2	4
51	31 31 42.3	159 04 39.5	5	2	3	4
52	31 31 40.1	159 04 44.2	5	2	3	4
53	31 31 51.2	159 04 33.4	1	1	3	4
54	31 31 53.3	159 04 36.4	1	1	3	4
55	31 31 52.2	159 04 22.9	6	3	2	4
56	31 31 53.9	159 04 18.5	6	3	2	4
57	31 31 58.8	159 04 10.6	1	1	2	4
58	31 31 55.4	159 04 07.2	1	1	2	4
59	31 31 48.6	159 04 04.5	1	1	2	4
60	31 31 45.4	159 04 01.5	1	1	2	4
61	31 32 07.3	159 04 20.4	1	1	3	4
62	31 32 07.6	159 04 23.4	1	1	3	4
63	31 32 21.0	159 04 29.5	1	1	4	4
64	31 32 24.7	159 04 34.6	1	1	4	4
65	31 32 18.5	159 04 40.1	6	3	4	4
66	31 32 20.2	159 04 45.1	6	3	4	4
67	31 31 59.9	159 04 37.7	3	1	3	4
68	31 32 03.4	159 04 38.6	3	1	3	4
69	31 32 07.8	159 04 49.6	3	1	3	4
70	31 32 10.8	159 04 53.1	2	1	3	4
71	31 32 17.2	159 04 50.3	7	3	3	4
72	31 32 32.4	159 04 59.4	7	3	5	4
73	31 33 05.1	159 04 32.3	6	3	4	4
74	31 33 03.1	159 04 37.5	6	3	4	4
75	31 33 09.8	159 04 58.1	9	2	5	4
76	31 33 09.4	159 04 54.4	9	2	5	4
77	31 33 19.0	159 04 43.9	1	1	5	4
78	31 33 23.4	159 04 40.5	1	1	5	4
79	31 33 30.9	159 04 36.9	5	2	5	4
80	31 33 34.5	159 04 35.8	5	2	5	4
81	31 33 43.6	159 04 34.2	5	2	5	4
82	31 33 40.6	159 04 35.3	5	2	5	4
83	31 33 58.0	159 04 32.9	5	2	5	4
84	31 34 03.2	159 04 31.5	5	2	5	4

85	31 32 33.6	159 04 40.9	6	3	4	4
86	31 32 33.2	159 04 45.6	6	3	4	4
87	31 32 46.7	159 04 40.5	8	3	4	4
88	31 32 43.4	159 04 41.5	8	3	4	4
89	31 32 52.0	159 04 42.0	1	1	4	4
90	31 32 55.1	159 04 39.7	1	1	4	4
91	31 32 37.4	159 04 54.2	1	1	5	4
92	31 32 37.7	159 04 57.7	1	1	5	4
93	31 32 42.3	159 05 06.2	1	1	5	4
94	31 32 43.9	159 05 10.7	1	1	5	4
95	31 32 49.3	159 05 26.8	1	1	5	4
96	31 32 52.7	159 05 27.4	1	1	5	4

Appendix C. Description of start point and turning point for all transects (A–G)

See Figure 2 for a map of the Lord Howe Island settlement area showing the seven transects. The protocol for these transect counts is included below.

Description of each transect location

A. Intersection of Neds Beach Road and Lagoon Road to the bridge at Old Settlement Creek.

B. Intersection of Neds Beach Road and Lagoon Road to Neds Beach bathing huts.

C. Intersection of Anderson Road and Neds Beach Road to the corner at the top of Middle Beach Road.

D. Intersection of Anderson Road and Muttonbird Drive up to and along Skyline Drive down McGees Parade to the intersection with Anderson Road.

E. Intersection of Middle Beach Road and Lagoon Road up Middle Beach Road to Anderson Road turning right (S) and down Anderson Road to Bowker Avenue walking track (which is a little difficult to see but is on the W or right hand side of the road and marked by a small triangular trail marker).

F. Intersection of Middle Beach Road and Lagoon Road to the gate at the corner of the airfield at Windy Point.

G. Intersection of Neds Beach Road with Lagoon Road to the intersection of Middle Beach Road and Lagoon Road (beside the LHI Museum).

Protocol for transect counts

1. Count all species of birds and Include all seen or heard on a slow walk from the defined start point to the defined finish point (outward count) and, as a new count, on the return walk to the start point (return count). Keep these two counts separate.

2. Count in the evening (starting not before 5PM in September).

3. Indicate which transect you have counted and include your name and the date.

4. Record the start and finish time for your outward count **and** your return count. Complete the counts as close as possible in the time indicated. Counts should be made during a **very slow walk** and the suggested times will achieve this objective.

5. Count all individuals you detect both sides of the road. There is no particular limit on distance but it would be reasonable not to include calls from birds or sightings that are, say, more than 50 metres from the roadside. Do not worry that you might count the same individual or individuals that could have been be seen on another transect at the transect intersections. Just include what you see or hear as part of your transect count.

Appendix D. Bird species recorded at 96 surveyed plots, LHI, 2019

Species nomenclature and names follow those recommended by the latest IOC listing. See Gill, F & D Donsker (Eds), 2019, IOC World Bird List (v9.2). doi:10.14344/IOC.ML.9.2. For some species we use a simplified alternative in this report.

Name used in this report	*IOC recommended name, if different*	*Scientific name*	*Subspecies*
Feral Duck[1]	Mallard	*Anas platyrhynchos*	
White-faced Heron		*Egretta novaehollandae*	
Woodhen	Lord Howe Woodhen	*Gallirallus sylvestris*	
Buff-banded Rail		*Gallirallus philippensis*	
Swamphen	Australasian Swamphen	*Porphyrio melanotus*	
Masked Lapwing		*Vanellus miles*	*novaehollandiae*
Feral Pigeon	Rock Dove	*Columba livia*	
Emerald Dove	Pacific Emerald Dove	*Chalcophaps longirostris*	*rogersi*
Sacred Kingfisher		*Todiramphus sanctus*	*vagans*
Pied Currawong		*Strepera graculina*	*crissalis*[2]
Golden Whistler	Australian Golden Whistler	*Pachycephala pectoralis*	*contempta*[2]
Magpie-lark		*Grallina cyanoleuca*	*cyanoleuca*
Welcome Swallow		*Hirundo neoxena*	*neoxena*
Tree Martin		*Petrochelidon nigricans*	
Silvereye		*Zosterops lateralis*	*tephropleurus*[2]
Common Starling		*Sturnus vulgaris*	
Blackbird	Common Blackbird	*Turdus merula*	
Song Thrush		*Turdus philomelos*	

Note:
1. Includes hybrids with Pacific Black Duck, *Anas superciliosa*. 2. Endemic subspecies

Appendix E. An examination of the effects of various eradication baiting regimes

With the complexity of the forest/settlement interface various methods of laying rodent bait were required. In general, aerial baiting occurred over the forested northern and southern ends of the island with bait stations occurring in the settlement area and a combination of bait stations and hand broadcasting throughout the buffer zone.

The 96 bird survey plots were distributed throughout the lowlands resulting in 26 plots being aerial baited within the forested northern end of the island, 22 plots aerial baited within the forested southern end of the island and the remaining 48 plots baited by hand broadcasting or bait stations in the settlement and buffer zone. The Transit Hill area was included in the southern end.

A series of generalized linear mixed models were fitted to the data from the six surveys. Categorial factors were created in an attempt to test a) if the counts in 2019 were different from the previous years, b) the if the bait delivery protocol was a significant predictor of the observed counts and c) if there were a significant interaction between the two factors. The statistical models fitted to the data are different from that fitted and described in the body of the main report. In answering the two main questions asked in this paragraph, **vegetation group and habitat zone are not accounted for** and this may have an impact on the interpretation of the main effects; rodent control and baiting protocol.

A significant result for the first question does not in itself indicate that the rodent control program has had an effect on the observed counts but does suggest that the 2019 counts were different from the counts in the years 2013 to 2018. A significant result for the bait delivery protocol does suggest that there may be differences due to the bait delivery technique but there are spatial (zone) confounding issues here that these preliminary analyses are unable to tease apart. The significant interaction effect needs further analysis; the preliminary interpretation is that the 2019 rodent control treatment has had an effect that is different for the three bait areas compared to the same groups of sites in the years 2013 to 2018. Without taking into account the effects of vegetation group or habitat zone, as we have done in the main body of the report, the fitted models suggest that the Buff-banded Rail, Magpie-lark and Swamphen show a decline with the Golden Whistler and Welcome Swallow showing a slight increase in 2019 with no differences for the Emerald Dove, Sacred Kingfisher, Blackbird and Silvereye compare with previous surveys.

The Emerald Dove, Swamphen and Sacred Kingfisher show no bait effects between the three baiting areas whilst the Buff-banded Rail, Blackbird, Welcome Swallow and Silvereye may be affected although this could be due to the effects of vegetation group or habitat zone. The Golden Whistler and the Magpie-lark show interaction effects between years of survey and baiting treatment and so it is not immediately obvious if either species are responding to the different rodent control treatment.

This preliminary analysis provides some answers to the role of baiting on adult mortality during and immediately after the baiting program but does not give any indication of the long-term impacts of the potential adult mortality or the reproductive outcomes that may result from the rodent eradication.