FINAL REPORT

Brolga Movements and Spatial Requirements During Breeding, south-west Victoria

PREPARED FOR

Willatook Wind Farm Pty Ltd

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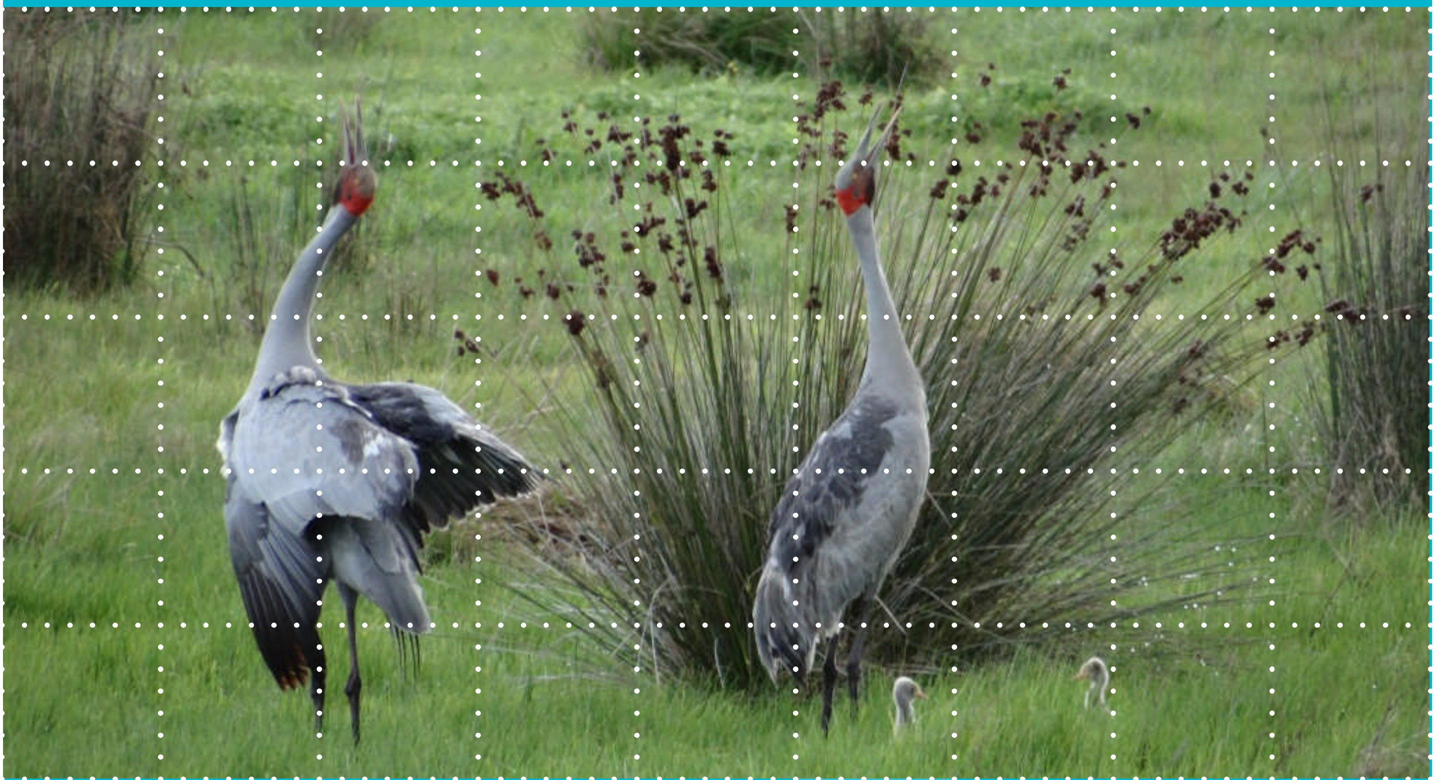

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Cover Photo: Brolga pair with two-week old chicks from nest four, 25 kilometres west of the proposed Willatook Wind Farm -

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1 INTRODUCTION

Ecology and Heritage Partners Pty Ltd was commissioned by Willatook Wind Farm Pty Ltd to undertake additional investigations on the nesting requirements of the State-significant Brolga Grus rubicunda at the proposed Willatook Wind Farm. Previous fauna assessments for the Willatook Wind Farm have been undertaken between 2009 – 2011 (Ecology and Heritage Partners 2011). These studies identified a number of Brolga breeding records within the proposed wind farm boundary and surrounding areas, and triggered a variety of further work, including the study detailed in this report. Other work regarding Brolga has included detailed consultation with landholders with Brolga records on their property in and around the wind farm, assessment of the habitat quality at the site of each breeding record, aerial surveys to detect Brolga nests and on-going Brolga monitoring.

Cranes, both overseas and in Australia, have been identified as being prone to collision with power lines (Goldstraw and Du Gueslin 1991; Kuvlesky et al. 2007; Janss and Ferrer 2000), although this does not specifically relate to turbine collisions. Brolgas, as an Australian representative of the Crane family, are therefore also seen as being potentially impacted by collisions with aerial infrastructure, such as wind turbines. Due to the perceived risk posed to Brolga by wind farms in Victoria, the Victorian Department of Environment and Primary Industries (DEPI) has developed guidelines for wind farm developments specifically in relation to Brolga in Victoria (DSE 2012). These guidelines outline a conservative approach to assessing and managing the effects of both individual wind farms and the cumulative impacts of the wind industry on the Victoria Brolga population. The objective of the guidelines is to ensure that there is no 'net effect' of wind farms on the Brolga, with the goal of achieving a positive effect for the population as a whole.

The impact of wind farms on Brolgas is one of the key environmental issues facing the industry in south-western Victoria (DSE 2012), although there are no reports of Brolgas being injured or killed at the wind farms currently in operation (AusWEA undated). Wind farms have the potential to impact on the Brolga in the following ways:

- Habitat loss by removal of wetlands and nearby pasture (foraging) habitats as a result of the construction of wind farm infrastructure;
- Collision with wind turbines, power lines and monitoring equipment;
- Disturbance of birds leading to displacement and exclusion from areas of suitable habitat or changes in behaviour; and,
- Creation of barriers to flying birds, interrupting migratory movements between important habitat areas or disrupting local flight paths.

To mitigate against these potential impacts, the DEPI Brolga guidelines have identified two key Brolga habitats requiring protection – breeding sites and flock roost sites (DSE 2012).

Under the guidelines (DSE 2012), a breeding site is defined as 'the nest of a Brolga breeding pair and the perimeter of the surrounding wetland. This definition also includes wetlands that contain suitable habitat for breeding, and that have a previous Brolga breeding record. All such wetlands are considered to contain suitable habitat, except those that have been permanently drained or planted with trees.

Siting wind turbines and other infrastructure to avoid impacts on Brolga breeding sites is an important strategy to avoid potential wind farm impacts on Brolgas. Turbines should be sited to 'exclude any significant reduction in breeding success caused by turbines' (Brolga Scientific Panel 2008) and will be achieved by "establishing turbine-free areas around all potential Brolga nesting sites sufficient to have no significant impact on the likelihood of successful reproduction" (DSE 2012). To achieve this goal, the Brolga guidelines recommend a turbine-tree buffer distance of 3.2 kilometres from breeding sites, however the guidelines acknowledge that the spatial requirements of Brolgas are not well known, and "a proponent may propose reduced buffer areas providing they can be shown to meet the objectives set for breeding…habitat" (DSE 2012). The guidelines also recommend that the reduced buffers should be based on site-specific investigations, as Brolga breeding home ranges are likely to vary with local habitat quality and extent, and seasonal conditions (DSE 2012).

A variety of avenues were explored between Willatook Wind Farm Pty Ltd, DEPI and Ecology and Heritage Partners to provide information on the breeding area requirements of Brolgas. This included aerial surveys, liaison with local landholders and experts, and inspection of previous nest records. In 2011, DSE suggested that Willatook Wind Farm Pty Ltd facilitate an analysis of existing Brolga nest data collected by other proponents with the intention of determining the home range requirements of brolga through meta-analysis of this existing data. DSE sourced the data and engaged Deakin University to undertake the analysis, however Deakin found the data was not of a suitable quality to do further analysis (Ben Purcell, Willatook Wind Farm Pty Ltd, *pers. comm.* 2012).

With the failure of these methods to contribute useful information to the determination of site-specific buffers around Brolga nests Willatook Wind Farm Pty Ltd immediately engaged Ecology and Heritage Partners Pty Ltd to undertake an independent Brolga nest monitoring program, the methodology of which was developed in consultation with DEPI. The purpose of this work was to understand the movements and spatial requirements of Brolgas during their breeding attempts, determine the spatial requirements of Brolgas to successfully rear chicks to fledging at the proposed Willatook Wind Farm. The study commenced in 2011 but was abandoned due to an inability to locate active nests. The study was resumed during the 2012 nesting season. This work represents a component Level Two assessment under the Brolga guidelines (DSE 2012). Other components of a Level Two Assessment (DSE 2012) have been undertaken previously by Ecology and Heritage Partners (aerial and roaming surveys: Ecology and Heritage Partners 2011). This information could then be used by Willatook Wind Farm Pty Ltd to apply site-specific buffers around Brolga breeding sites (Step 1 of the Level Three assessment: DSE 2012), such that the development of the wind farm would have no significant impact on the likelihood of successful Brolga reproduction.

2 METHODS

2.1 Brolga *Grus rubicunda*

Brolgas breed between July and December in a variety of shallow wetlands or in the shallows of deeper wetlands, among tussock-grass, sedge or canegrass or in grassy tidal flats (Marchant and Higgins 1993). During breeding, Brolga pairs establish exclusive territories which they vigorously defend from other Brolgas (Marchant and Higgins 1993). This defended territory includes the wetland containing the nest and surrounding foraging areas, and may be up to 256 hectares in size (Arnol, White, and Hastings 1984). This home range area would represent a radius of containment of approximately 900 metres, however no methods are reported to derive this value. Wetlands which retain suitable conditions may be used repeatedly over long periods of time, but wetlands which appear suitable may not be used in any given year due to a variety of reasons (e.g. local water levels during courtship, availability of other breeding sites, presence of other pairs). Incubation of eggs last 28-31 days, and young are able to leave the nest at 1-2 days old, while chicks fledge (i.e. are able to fly) at approximately 14 weeks old (Marchant and Higgins 1993). Initially parents and chicks return to the nest, or close-by each night (Ecology and Heritage Partners pers. obs.), however as chicks get older families are thought to roam increasingly far from the nest site (R. Hill DEPI *pers. comm*. 2012).

Avoiding all potential impacts to Brolga breeding home ranges is a key goal when designing wind turbine facilities, and one component of this is the application of turbine-free buffers around breeding sites which occur in wetlands suitable for breeding (DSE 2012). Under current guidelines, a buffer distance of 3.2 kilometres is considered to be sufficient to have no significant impact on the likelihood of successful reproduction at that wetland. The guidelines do, however, acknowledge that Brolga spatial requirements during breeding are not well known, and reduced buffers can be proposed if these can be shown to the satisfaction of DEPI to meet the objectives set out in the guidelines for breeding habitats to the satisfaction of DEPI (DSE 2012). Such reduced buffers have been developed for the Penshurst Wind Farm to the satisfaction of DEPI (then DSE), reducing the buffer distance from 3.2 kilometres to 687 metres (Biosis Research 2011).

2.2 Study Area

The proposed Willatook Wind Farm site is located approximately 30 kilometres north of Port Fairy and 250 kilometres west of Melbourne, in southwest Victoria (Figure 1), and approximately 15 kilometres south of the proposed Penshurst Wind Farm. The wind farm site covers approximately 5,220 hectares of mainly agricultural land (i.e. livestock grazing, cropping) with native vegetation within the general area being largely restricted to roadside reserves.

According to the DEPI Biodiversity Interactive Map (DEPI 2013) the proposed Willatook Wind Farm site occurs within the Victorian Volcanic Plain bioregion, the Glenelg Hopkins Catchment Management Authority and the Moyne Shire Council areas.

Due to a lack of nesting within the proposed Willatook Wind Farm and immediate surrounds, the study area was expanded to include a much larger area. In total, wetlands visible from public roads within an area of approximately 6000km^2 was searched, stretching east-west from Lismore to Portland and north-south from Penshurst to Port Fairy – this area contains a large number of Brolga records (Figure 2). Only wetlands visible from roads were checked due to the survey methodology chosen, which required regular nest checks throughout the day and nests difficult to access would significantly limit the amount of data able to be collected. The study undertaken by Biosis Research (2011) in relation to the proposed Penshurst Wind Farm also expanded the study area well beyond the wind farm site despite the site containing a larger number of Brolga nest records.

2.3 Liaison with Government Agencies

The methods employed here were developed in discussion with DEPI and Symbolix Pty Ltd (statistical consultants). Discussions were initiated in October 2011 regarding the design of surveys, considering the practical requirement of fieldwork, the requirements of the Brolga guidelines and statistical robustness. Following several meetings and many emails between Ecology and Heritage Partners, Symbolix Pty Ltd, Willatook Wind Farm Pty Ltd and DEPI (then the Department of Sustainability and Environment), DEPI endorsed the field and statistical methodology described here on 21 November 2011 (R. Hill, DEPI, via email 21 November 2011). DEPI were kept up to date throughout the field season, and there were another three meetings following data analysis by Symbolix Pty Ltd to discuss the outcomes and implications of the surveys. In total five teleconferences were held between Willatook Wind Farm Pty Ltd, DEPI and Ecology and Heritage Partners (details in Appendix A), while there was also numerous telephone and email correspondence.

2.4 Nest Searching and Monitoring

To locate Brolga nests, all Brolga 'breeding' records from the Victorian Biodiversity Atlas (VBA) (DSE 2011) were plotted on to maps of south-western Victoria (e.g. Figure 2). Information on active nests during the 2012/13 season were sought from staff of DEPI, Inka Veltheim (PhD student researching Brolgas), the Brolga Recovery Group and in discussion with local landholders throughout the study area, particularly those that had previously indicated the presence of Brolga on their property during landowner surveys. The site of each record was then visited, where possible, up to six times between September and December 2012 to identify localities where Brolga were breeding. Additional wetlands were scanned from roadsides and other publically accessible areas during field visits. Records far from roads, or not easily accessible, were excluded due to the data collection methodology, unless a Brolga pair was flagged at that location by a landholder and property access was granted.

For each new nest, the stage of breeding on discovery, location of each Brolga and approximate nest location was recorded. Nests were then visited repeatedly until the nesting attempt was successful (i.e. chicks fledged) or was abandoned. Nest sites were visited a maximum of three times per day (once each in the periods 7-11am, 11am-3pm, 3-7pm) to avoid issues associated with autocorrelation of the data (de Solla, Bonduriansky, and Brooks 1999; Otis and White 1999). Observations were made using binoculars from a vehicle to minimise disturbance to Brolgas. During each visit the location of each Brolga was noted (as both a distance and direction from the nest, or plotted directly on aerial photographs of the site), as was the activity of each Brolga and the presence of eggs or chicks (where possible). Accuracy with both methods was considered to be +/- 10 metres, potentially better once the observer was familiar with the pair and the area they used. Typically Brolgas were recorded on the nest or foraging nearby, however sometimes one of the Brolga pair was not observed. Observing neither Brolga in the area of the wetland containing the nest (usually within one kilometre) for three consecutive visits over at least two days was judged sufficient to assume the nest abandoned. Subsequent opportunistic visits to abandoned nest sites confirmed this was a valid assumption to make.

2.5 Data Analysis

Brolga and nest locations were digitised by hand and forwarded to Symbolix for data validation and detailed analysis. Home range size (in hectares) was determined for each nest separately, and for a combined dataset using the nest site of each pair to unite the locations. Asymptote analysis was used to determine if enough locations had been collected for the pair to all a stable home range size to be calculated. From these locations a radius of containment was also calculated for each nest, and combined, to be applied at nest sites which were not monitored in the 2012/13 breeding season. Full details of analysis methods are described in the Symbolix report (Appendix B).

Analyses from data collected in the 2012/13 breeding season was compared with publically available brolga home range data from elsewhere in south-west Victoria. Only one such available source was considered useful, as it used similar data collection and analysis methods – brolga home range monitoring for the proposed Penshurst Wind Farm (Biosis Research 2011). The purpose of this comparison was to determine if consistencies or discrepancies in brolga behaviour exists between different areas and time periods, and assuming there was a suitable correlation between the two studies, allow for an increased confidence in the results presented here. This approach was agreed to by DEPI in a meeting on 7 March 2013 (Willatook Wind Farm Pty Ltd *unpubl. meeting minutes*).

3 RESULTS

Five wetland areas with nest records were checked within the proposed Willatook Wind Farm boundary (Figure 1); none of which had an active Brolga nest. A further 23 wetland areas with nest records were checked within the surrounding 10 kilometre area; once again none were found to have an active Brolga nest. All wetlands visible from roads were also checked within these two areas. The study area was then expanded to cover a large proportion of the known Brolga breeding range in south-western Victoria. In total, nine nests were found within the expanded study during the 2012/13 Brolga breeding season (Table 1, Figure 3). In relation to the proposed Willatook Wind Farm, the closest nest was 10 kilometres north, while the furthest away was 88 kilometres east. A small number of additional nests were known from within this expanded study area (through discussions with landholders); however public access issues, the sequence of nest discovery and the sampling methodology prevented more nests being monitored.

The first nest was located on 29 July 2012, and the last new nest for the season on 2 October 2012. All nests were found when Brolgas were brooding eggs, apart from Nest 7, which was found when the Brolga pair was still building their nest. As nests were found on different days, and lasted for different durations, the number of location records for Brolgas associated with each nest was variable. Seven nests had sufficient data for analysis: for these nests there were between 16 and 56 Brolga observations. All nests monitored in the 2012/13 breeding season failed; one nest contained an infertile egg, while the cause of failure at the other eight nests is unknown, although intraspecific competition was implicated at two nesting attempts. Two Brolga pairs (at Nests 2 and 5) had a second breeding attempt after their first attempt failed. Chicks were recorded at two nests, but these disappeared at approximately three to four (Nest 4) and seven (Nest 5) weeks old respectively, and were presumed predated as the (probable) parents were later observed nearby without chicks.

Home ranges, calculated using the kernel method (Worton 1989) for the combined dataset, were 52.3 and 80.1 hectares for 95% and 99% of all locations respectively (Table 2). Six nests had sufficient data for asymptotic analysis. Brolga pairs at Nests 4, 5, 6 and 8 showed a stable home range over the monitoring period (Figure 4 of Appendix B). The pair at Nest 7 had a declining home range, due to the regular absence of the individual not on the nest, and the Brolga pair at Nest 9 had an increasing home range size over the monitoring period. Based on the combined dataset, radii of containment were 497 and 679 metres which would contain 95% and 99% respectively of all locations (Table 2).

Analyses are available on an individual nest basis, however as no nests were located within the proposed Willatook Wind Farm boundary, a combined dataset was considered more appropriate. Full details of results are described in the report prepared by Symbolix Pty Ltd (Appendix B).

Table 1. Details of Brolga breeding attempts monitored during the 2012-2013 breeding season.

Pair	Distance from Willatook wind farm boundary	Date of first observation	Status at first observation	Breeding end date	Status at end of breeding attempt	Birds observed / Not observed	Reason for end of breeding attempt	Comments
Pair 1*	22 kms north	29 Jul 2012	Egg	28 Aug 2012	Egg	4 / 0	Nest failure, reason unknown	
Pair 2	85 kms east	10 Sep 2012	Egg	18 Sep 2012	Egg	18 / 12	Nest failure, possible intraspecific competition	Landholder said nesting started 17-Aug-12. Pair attempted at re-nest at the end October 2012, laid 2 eggs, nest failure, reason unknown.
Pair 3*	74 kms east	26 Aug 2012	Egg	between 27 Aug and 11 Sep 2012	Egg	2 / 0	Nest failure, reason unknown	
Pair 4	25 kms west	10 Sep 2012	Egg	26 Sep 2012	2 x Chicks, 3-4 weeks old	28 / 6	Displaced by new pair, fate of chicks unknown	
Pair 5	71 kms east	12 Sep 2012	Egg	06 Jan 13	1st attempt: Egg 2nd attempt: Two chicks, 6-7 weeks old	27 / 9	Both chicks no longer present, assumed predated.	First nesting attempt observed 12-Sept 2012. Nest failed, reason unknown. Second nesting attempt, two chicks hatched 21-Nov 2012. First chick missing mid-Dec 2012, second chick disappeared, assumed predated, 6 Jan 2013.
Pair 6	10 kms north	12 Sep 2012	Egg	between 20 and 26 Sep 2012	Egg	16 / 0	Nest failure, reason unknown	
Pair 7	73 kms east	16 Sep 2012	Nest building	between 1 and 12 Nov 2012	Egg	39 / 17	Nest failure, reason unknown	Egg(s) laid between 17 Sep 2012 and 26 Sep 2012
Pair 8	62 kms east	26 Sep 2012	Egg	between 17 and 31 October 2012	Egg	35 / 5	Nest failure, reason unknown	
Pair 9	88 kms east	02 Oct 2012	Egg	03 Dec 2012	Egg	56 / 10	Nest failure, egg seen in abandoned nest	Egg assumed to be infertile given length of incubation period

*excluded from analyses due to low sample sizes

4 DISCUSSION

This report is only the second to present data on the movement of the Brolga during its nesting period in south-west Victoria using a statistically valid approach (see also Biosis Research 2011). It shows that Brolga pairs have only limited activity areas, and, 99% of the time, will be found within 679 metres of the nest (Table 2). The 99% percentile was intentionally used, as this captures the full range of Brolga movements and would represent the total area required for breeding.

Given that none of the pairs at nests monitored during the 2012/13 breeding season successfully fledged chicks, there is the possibility that the data presented here do not represent sufficient area for Brolga pairs to undertake successful reproduction. There are a number of potential considerations when considering the accuracy and validity of the data presented in this report, and these are discussed individually below. These considerations reflect concerns and issues raised during both the methodological discussions prior to fieldwork and meetings following the analysis of the data. The key issues raised in regard to the current data were a lack of data at the chick stage, the importance of non-observations and the value of site-specific data.

To inform this discussion data from the 2012/13 breeding season was considered with other available data on movements and breeding requirements of Brolga in Victoria. Arnol *et al.* (1984) suggested that Brolgas had a breeding home range area of up to 256 hectares, but provided no supporting evidence for this claim. Brett Lane & Associates (2008) also monitored Brolga during their breeding attempts in 2007 for the Stockyard Hill Wind Farm, however their monitoring was qualitative and focussed on movements rather than home range areas. These studies are not considered further due to a lack of supporting information and statistical robustness. In the 2009/10 Brolga breeding season, Biosis Research (2011) monitored eight pairs of Brolga from around the Penshurst and Darlington areas during each Brolga pair's breeding attempt. As in this study, not all breeding attempts were successful – chicks fledged at only three nests and the quantity of data varied between nests. Data collection and analysis methods were essentially the same as those used in this study (E. Stark, *pers. comm*. 2013), and as such results are directly comparable. For the combined dataset from the Biosis Research (2011) study (eight nests), 95% and 99.9% of all observations were contained within a radial distance of 513 and 687 metres respectively from the nest site (radius of containment method using the average location as the central point and assuming Pair 10 is actually two pairs (Symbolix Pty Ltd 2010)). Despite the different years and geographic locations, both the 95% and 99% (or 99.9%) buffer radii are very similar when comparing data from the two studies.

Given the similarities between the two studies, and the total number of pairs monitored, it is unlikely that monitoring more nests and gathering further data for analysis using the methods described here would significantly change the home range areas or radii of containment required to contain all brolga movements during breeding attempts. This view is supported by Symbolix Pty Ltd (E. Stark *pers. comm.* April 2013).

4.1 Data During the Chick Stage

This study had two Brolga pairs where movement data was collected while they had chicks (Nests 4 and 5). Neither of these breeding attempts was successful: the chicks at Nest 4 disappeared when three to four weeks old, and the chicks at Nest 5 when they were six to seven weeks old. These failures mean that the current data does not include movement information for the period between seven weeks and fledging (which occurs at approximately 14 weeks: Marchant and Higgins 1993). This is a key period when determining appropriate turbine-free buffers (R. Hill DSE, *pers. comm*. 2013), especially if movements become larger as chicks grow. Despite the recorded nest failures, some information is available from during the observation period. For both pairs monitored, their home range did increase as chicks became older (Table 2: note that this information only relates to movements up to when chicks are seven weeks old).

In contrast to the current study (2012/13), three Brolga pairs (Pairs 1, 10 and 17) monitored during the Biosis Research (2011) study raised chicks to fledging, and these pairs provide the best information of Brolga movements during the later chick stages. When the home range of each pair is considered separately (these results can be seen graphically in Table 3):

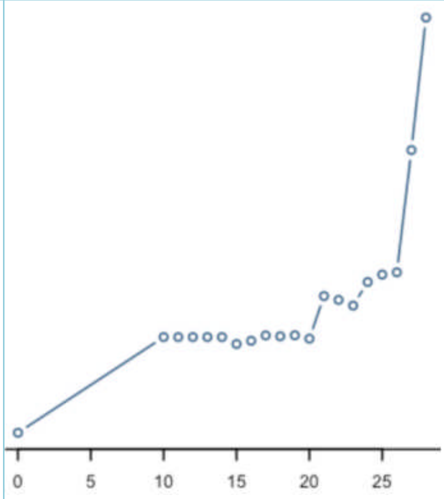
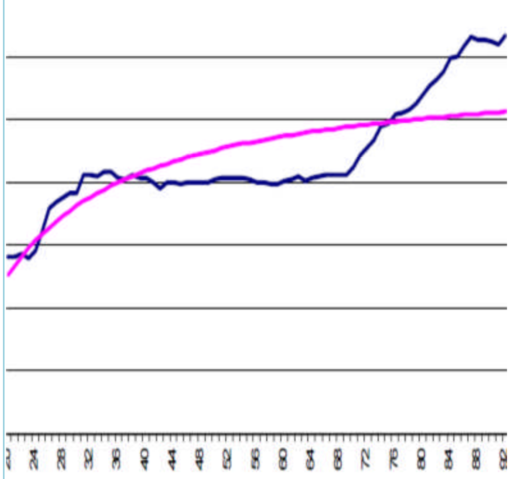
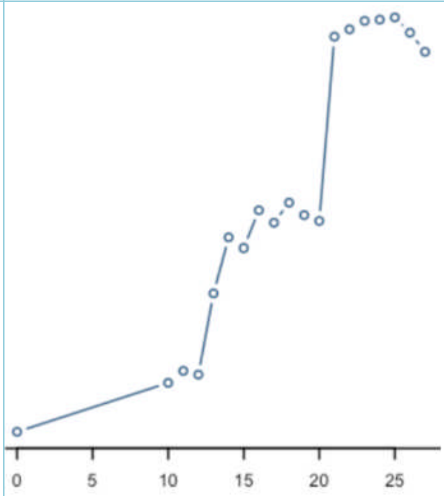
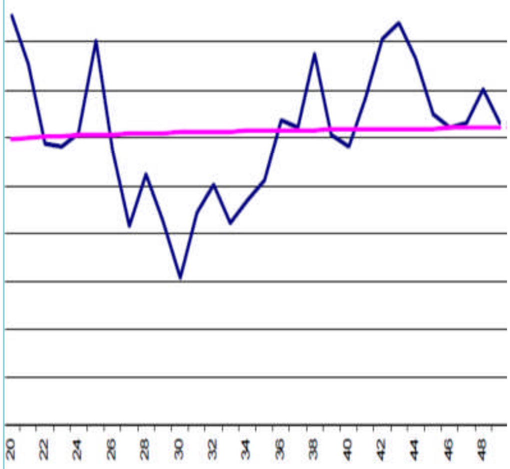
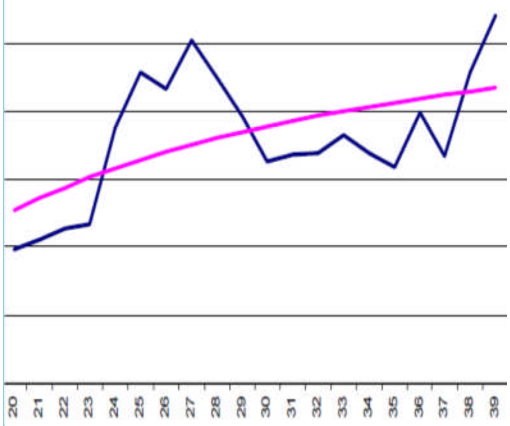
- Pair 1 increased their home range as the chick became older;
- Pair 10 showed no change in home range as the chick became older; while,
- Pair 17 showed no change in home range until the last two records before the chick(s) fledged. These last two records may actually be post-fledging, but where the birds had not moved out of view, in which case the home range of this pair would have not changed over the life of the dependent chick.

While it makes sense conceptually that as chicks grow and become more mobile they are likely to range further from the nest site, this is not supported by the data from Biosis Research (2011). Once chicks are mobile, Brolga pairs and their chicks can potentially wander anywhere, however despite this freedom the three pairs that fledged chicks in the Biosis Research (2011) report remained within 620 metres of their nest 99% of the time during the chick stage, departing this area only upon fledging. There were very few instances when Brolgas were not observed (15 instances in total: Biosis Research 2011), thus these home range values are likely to approximate the true home range for each pair during their breeding.

Table 2. Home range area and radii of containment for Brolga breeding home range – this study and Biosis Research (2011) studies. Each analysis treats all locations for that category (e.g. movements during incubation) as if they were recorded from a single pair. This is a conservative approach and gives equal weight to all location records when calculating home range areas and buffer radii.

Source	Home range area (hectares)		Radius of containment buffer (metres)	
	95%	99%	95%	99%
This study – all pairs	52.34	80.09	497	679
Biosis Research (2011) – all pairs	30.6	110.9	513	687
This study - movements during incubation	39.5	64.22	493	690
Biosis Research (2011) - movements during incubation	20.2	86	444	605
This study - post-hatching movements	53.33	80.12	529	628
Biosis Research (2011) - post-hatching movements	41.2	116.5	478	620

Table 3. Home range asymptotes for Brolga pairs with chicks, taken from Symbolix Pty Ltd reports (Symbolix Pty Ltd 2010; Symbolix Pty Ltd 2013).

This study		Biosis Research 2011	
Pair 4		Pair 1	
Pair 5		Pair 10	
		Pair 17	

A second approach to consider the importance of movements during the chick stage is to consider Brolga pair home ranges and radii of containment separately for the incubation and chick periods. In this study the home range was bigger (~20%), but the radius of containment smaller (~10%) for Brolga pair movements during incubation than with chicks (Table 2), although differences are not large in either case. For Brolgas monitored in the Biosis Research (2011) study, Brolga pairs had both a larger home range (~25%), and radius of containment (~4%) when they had chicks compared to when they were incubating (Table 2), however differences were, once again, small in both cases. Thus it appears that neither the home range nor radii of containment vary significantly when Brolga pairs have chicks compared to when they are incubating.

A further consideration is the role that a nest site plays in a successful breeding event, as once a chick is one to two days old it is mobile enough to leave the nest (Marchant and Higgins 1993). After this time the chick may return to the nest site each night, as when the nest site is surrounded by water it presents a relatively safe location away from predators. As a chick gets older two things happen: it becomes more able to defend itself from predators, and the wetland surrounding the nest site dries, allowing predator access to the nest site. These two events are generally likely to happen much earlier than fledging (e.g. the wetland where Nest 5 occurred in 2012/13 dried completely when the chicks were four weeks old), and it could be argued that once these events happen the nest site becomes no more important than any other area in the landscape.

4.2 Missing Observations

It was not always possible to locate both Brolgas during visits to nests, with the number of 'missing' observations variable between nests. Brolgas not observed may have been present and missed, or had moved to areas at which they were not detectable. Due to the Brolga's large size and the open habitat around nest sites, it is unlikely any Brolgas that were visible were missed. Local topography meant that the lines of sight were highly variable in different directions around each nest, and it is much more likely that Brolgas had moved out of sight. The distance of these moves is unknown, but areas only 100 metres from the nest were obscured for some nests due to the undulating landscape. While it is impossible to know where Brolgas are when they are not seen, elsewhere Brolgas have been recorded flying between 1.6 and 3.2 kilometres from their nesting site during the breeding period (Brett Lane and Associates 2008). While, it would be inappropriate to arbitrarily define locations for these undetected individuals, two options are possible:

- If these locations are closer to the nest than the maximum distance recorded, the home range areas and radii of containment would remain the same as reported here. There would be no change in this case as the current values reported use all data, thus include the maximum values recorded.
- If these locations are further from the nest than the maximum distance recorded, the home range areas and radii of containment are likely to increase. The likelihood and magnitude of this increase would be dependent on the spatial arrangement of the missing observations.

Missing observations were present in the data presented in the Biosis Research (2011) study, however their impact on the reported home range and radii of containment values was not discussed, nor considered in determining the home range requirements of nesting brolga (E. Stark, Symbolix Pty Ltd, *pers. comm.* 2013).

4.3 Low Sample Sizes and the Value of Site-specific Data

The Brolga guidelines specify site-specific investigations of Brolga breeding activity, as home ranges may vary with local habitat quality and extent (DSE 2012). The guidelines do not specify a maximum distance of a nest from a wind farm for it to be considered in a site-specific analysis, nor an approach to take if there are no active nests within a proposed wind farm boundary. Due to the low number of breeding Brolga pairs that may occur in or near a wind farm, there is a conflict between the desire to gain site-specific information, and the need to collect sufficient data from which to draw robust conclusions. In the case of this report, there was limited potential to gain site-specific information as there were no known nesting attempts within the proposed Willatook Wind Farm boundary during the 2012/13 breeding season. Increasing the size of the study area allowed more robust conclusions to be drawn through consideration of Brolga behaviour at more nests, but limited the conclusions' site-specific nature. Therefore, it is unclear how this requirement is to be implemented, however for the Penshurst Wind Farm, site-specific buffers were based on data from nests in and around the wind farm and from the Mortlake / Darlington region approximately 60 kilometres from the proposed wind farm.

Despite the limited nature of the existing data (seven nests in this study, eight in the Biosis Research (2011) report), there is an indication that nesting requirements do not vary considerably by the location of the site. Despite the different years and geographic locations of the two studies, home ranges and radii of containment values were very similar. It may be that Brolgas initiate breeding when suitable wetlands reach a certain level or area of inundation: if so, then breeding wetlands will initially all be of an approximately similar area. If Brolgas forage exclusively within that area, then Brolga movements will also be generally similar during this period. Variation in movements between breeding Brolga pairs would then be in response to local environmental conditions (e.g. rainfall or evaporation) affecting wetland size.

5 IMPLICATIONS

Analysis of Brolga movement data from seven breeding attempts showed a circular area of radius 679 metres encompassed all recorded movements for all Brolga pairs during their breeding attempts in 2012/13. The required nesting area reported here is very similar to that reported as part of a previous study into Brolga home ranges and movements (Biosis Research 2011), and given the different years and environmental conditions under which the two studies were undertaken, may represent the general area required by Brolgas for successful nesting in south-west Victoria. Given the number of nests monitored and similarity of results, further studies are unlikely to change these results significantly.

Based on this study and that by Biosis Research (2011), it appears that a turbine-free buffer distance of 700 metres would be sufficient to have no significant impact on the likelihood of successful reproduction. With the additional 300 metre radius buffer to 'avoid disturbance effects' (DSE 2012), applying a total buffer of 1000 metres around each valid nesting site would be a conservative approach to avoiding impacts on the breeding success of Brolgas. Such a buffer should be applied to all wetlands which have suitable Brolga breeding habitat and which contain a valid record of Brolga nesting.

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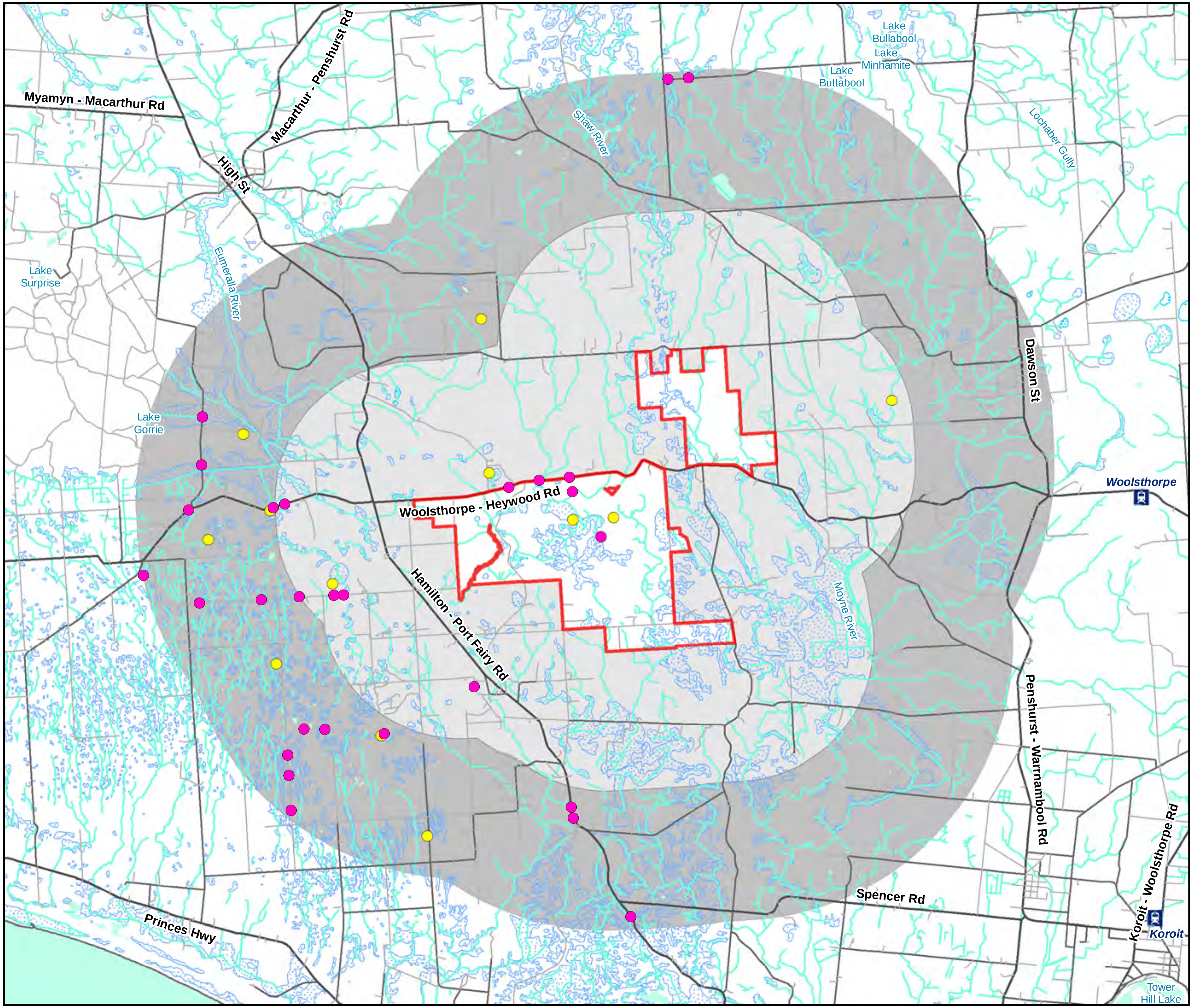
7 FIGURES



Legend

- Willatook Wind Farm boundary
- 5km buffer
- 10km buffer
- Wetlands checked
- Brolga records (VBA 2011)
- Major Road
- Collector Road
- Minor Road
- Minor Watercourse
- Permanent Waterbody
- Land Subject to Inundation
- Wetland/Swamp

Figure 1

Wind Farm boundary

Proposed Willatook Wind Farm

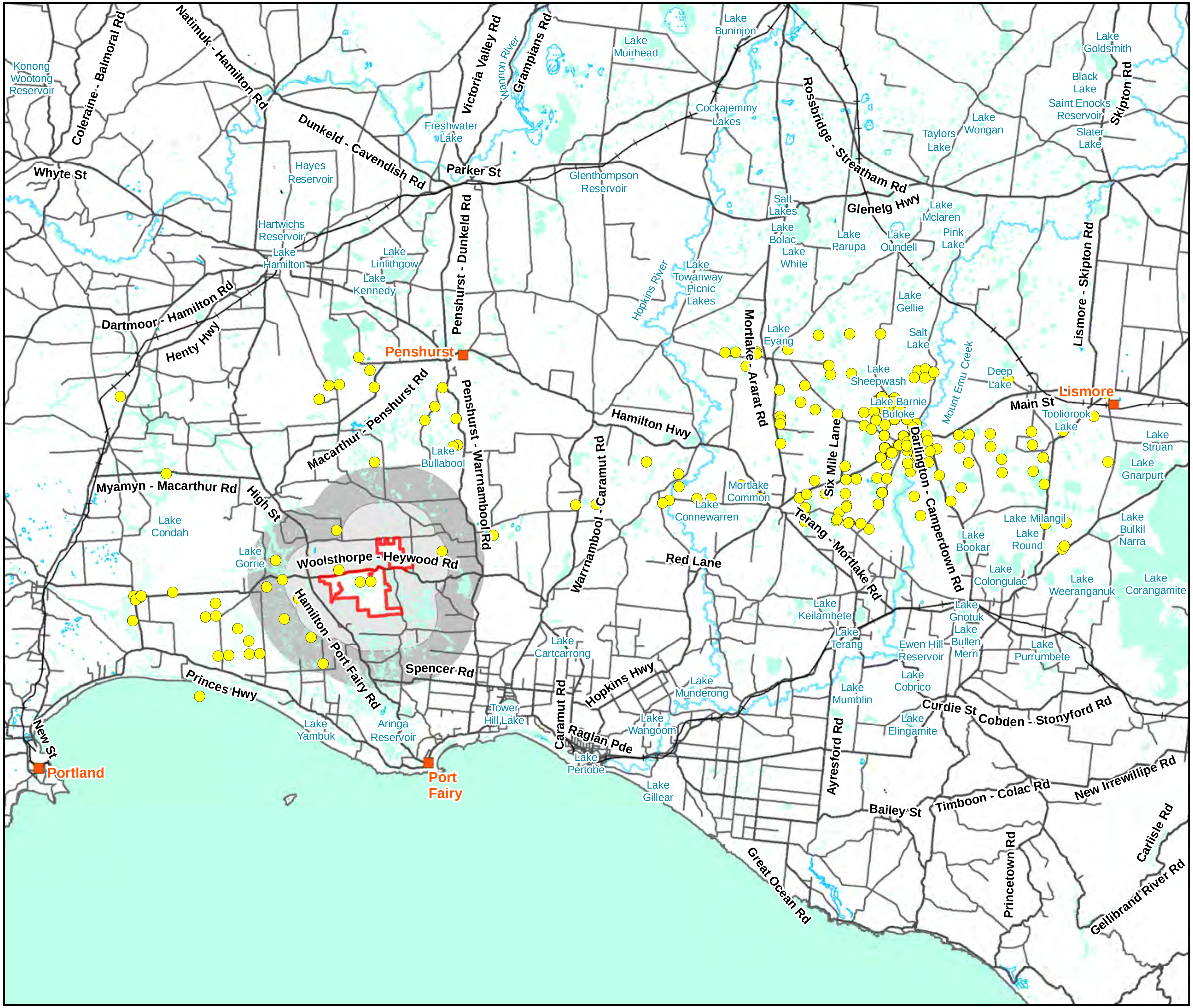
N

0 2 4

Kilometres

ecology & heritage partners

3506_Fig01_Willatook_Boundary 4/11/2013 melsley



Legend

- Willatook Wind Farm boundary
- 5km buffer
- 10km buffer
- Brolga breeding records (VBA 2011)

Figure 2

Survey extent and Brolga breeding records

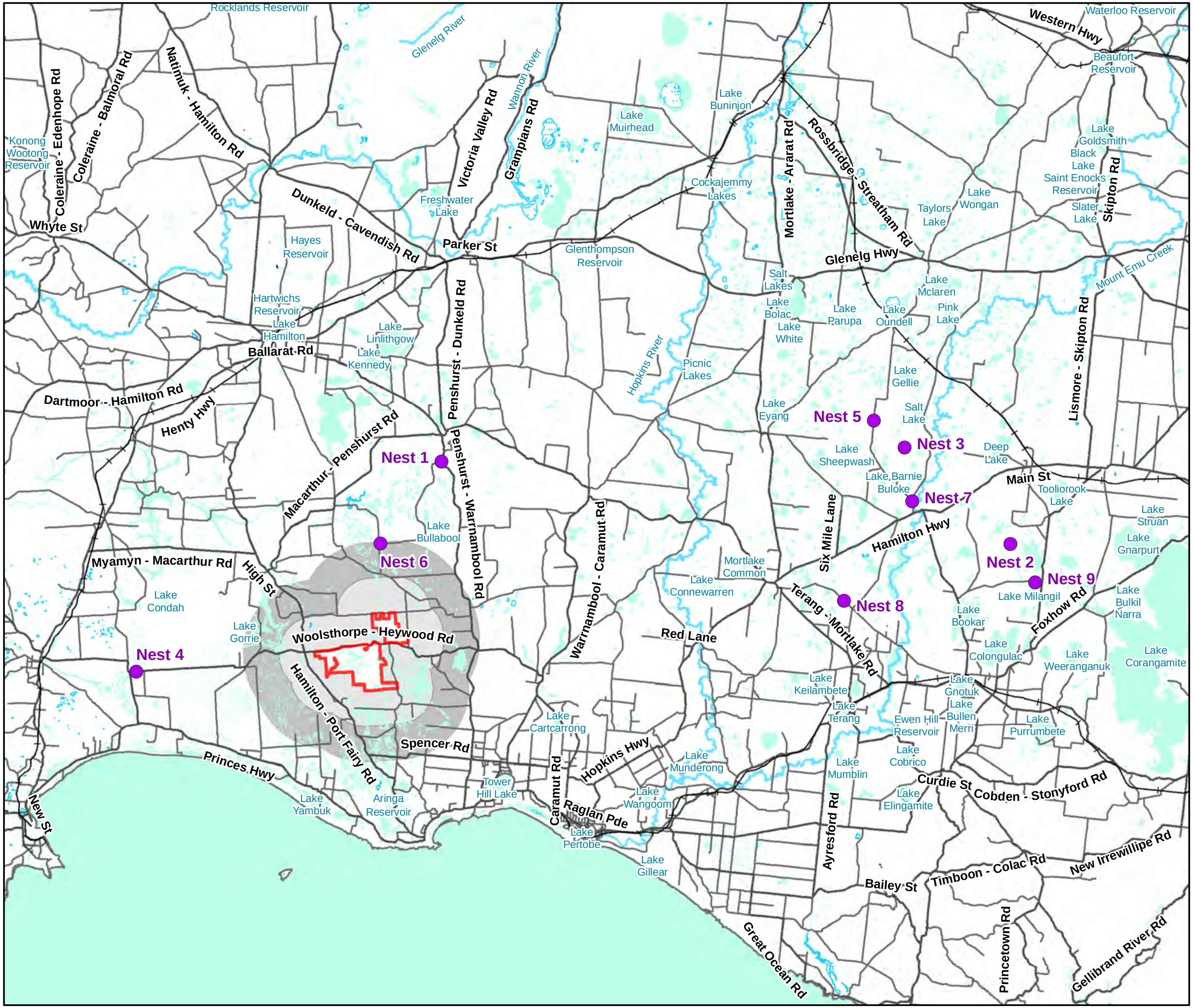
Proposed Willatook Wind Farm

N

0 5 10
Kilometres

ecology & heritage partners

3506_Fig02_Checked_Pot_Nesting_Hab 19/11/2013 melsley



Legend

- Willatook Wind Farm boundary
- 5km buffer
- 10km buffer
- Monitored Brolga nests

Figure 3

Brolga nests monitored in 2012/13

Proposed Willatook Wind Farm

N

0 5 10

Kilometres

ecology & heritage partners

VicMap Data: The State of Victoria does not warrant the accuracy or completeness of information in this publication and any person using or relying upon such information does so on the basis that the State of Victoria shall bear no responsibility or liability whatsoever for any errors, faults, defects or omissions in the information.

3506_Fig03_Monitored_Nests 4/11/2013 melsley

8 APPENDIX A

Details of minuted meetings between Willatook Wind Farm (WWF), DEPI Ecology and Heritage Partners (EHP) and Symbolix Pty Ltd for this project

Date	Organisation and personnel involved
17 October 2012	WWF – Ben Purcell, Aaron Sluczanowski DEPI – Richard Hill, Claire Tesselaar EHP – Aaron Organ, Clio Gates Foale
4 December 2012	WWF – Ben Purcell, Aaron Sluczanowski DEPI – Richard Hill, Claire Tesselaar EHP –Clio Gates Foale
11 February 2013	WWF – Ben Purcell, Aaron Sluczanowski DEPI – Richard Hill, Claire Tesselaar EHP –David Wilson
7 March 2013	WWF – Ben Purcell, Aaron Sluczanowski DEPI – Geoff Brooks, Richard Hill, Claire Tesselaar EHP –David Wilson, Clio Gates Foale Symbolix – Elizabeth Stark
24 April 2013	WWF – Ben Purcell, Aaron Sluczanowski DEPI – Geoff Brooks, Claire Tesselaar, Andrew Pritchard EHP –David Wilson, Clio Gates Foale Symbolix – Elizabeth Stark

Analysis of brolga home ranges

2012 breeding season

Issue Version 1.1

15th February 2013

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Version	Status	Date	Approved for release	Issued to	Copies	Comments
0.9	For review	12/2/13	S. Muir	D. Wilson, C. Gates-Foale	e	For client review
1.0	Issue	15/2/13	S. Muir	D.Wilson, C. Gates Foale	e	Incorporating client comments – minor changes
1.1	Issue	22/2/13	S.Muir	As above	E	Minor typographical changes

Approved for Release:

15/2/13

Signed Date

Limitation: This report has been prepared in accordance with the scope of services described in communications between Symbolix Pty Ltd and Ecology & Heritage Partners. Any findings, conclusions or recommendations only apply to the aforementioned circumstances and no greater reliance should be assumed or drawn by Ecology & Heritage Partners. Furthermore, the report has been prepared solely for use by Ecology & Heritage Partners and Symbolix Pty Ltd.

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1 Executive Summary

This report presents the results of a home range analysis of nine nesting brolga pairs (*Grus rubicunda)* during breeding and fledging. This analysis forms part of a larger avian risk assessment for a proposed development in south-west Victoria.

The objectives of this analysis are to provide

- An analysis of the suitability and limitations of the data collected to determine a statistically stable home range estimate (asymptotic analysis).
- Home range utilisation charts of the extent and shape of each pair's home range and an estimation of the area covered.
- A suggested nest buffer radius based on the home range data provided.

Brolga movement data was collected, compiled and validated by Ecology and Heritage Partners.

1.1 Data overview

The data provided consisted of observations of nine brolga nests. All nests failed, which limits the amount of data available for analysis. The number of individual brolga observations per nest varied between 2 and 56.

Only two nests recorded any chick activity. The other nests were only observed during the egg stage and approximately one half of all observations recorded the brolga on the nest.

Asymptote analysis showed that nests 4 through 7 show reasonably stable home ranges (though the small number of observations should always invoke caution). Overall, the data is suitable as an initial assessment of overall home range behaviour and size, but care must be taken due to the variability and size of the data set.

1.2 Key Findings

The home ranges were mapped individually and a combined map produced by translocating each point to a common nest value. Kernel home range estimation was used to find that these brolgas remained within an 80ha area surrounding their nest (to 99% confidence).

These home ranges are complex in shape and difficult to translate into buffer regions for risk mitigation. Circular buffer radii (measured from the nests) will normally contain a larger area than the more complex, underlying home range. Based on the combined data, we would expect to find nesting brolgas within 680m from their nest 99% of the time. Based on the largest home range, this radius increases to around 770m. This translates to a buffer of 145 – 190 ha.

Due to the variability and amount of data, we would consider these results an initial assessment of overall home range behaviour and size. We recommend that these results be validated against other data or literature where possible.

2 Data review

The provided data consisted of observations of nine brolga nests between the end of July and mid-December 2012. For each individual bird, the estimated location (latitude and longitude) was provided, and the presence of eggs or chick was noted (if possible). A description of the location/behaviour was also provided, along with the temperature and cloud cover.

During the observation period, all nine breeding pairs failed and only a small number of observations were possible for most nests (*D. Wilson, Ecology & Heritage Partners, pers. comms*). Nests 1 and 3 were excluded from the analysis due to the very low number of individual observations (Table 1).

Nest 2 had a combination of a low number of observations, which covered a small number of locations only. This meant that the home range area calculation was unstable and it has been excluded from individual analysis. The data is combined with other nests to contribute to average home range calculations.

	Nest 1	Nest 2	Nest 3	Nest 4	Nest 5	Nest 6	Nest 7	Nest 8	Nest 9
Number of surveys:	2	15	1	17	18	8	28	20	33
Number of individual brolga observations:	4	18	2	28	27	16	39	35	56
Number of observations with brolga on nest:	0	11	1	1	9	8	28	20	31
Breeding stages recorded:	Egg	Egg	Egg	Chick only	Egg & Chick	Egg	Egg	Egg	Egg

Table 1: Summary of surveys and brolga movements observed.

Only nests four and five recorded any chick activity. The other nests were only observed during the egg stage and approximately one half of all observations recorded the brolga on the nest (Table 1). The observations were distributed across the day (Figure 1), which suggests that the behaviour observed is reflective of overall brolga daytime movements.

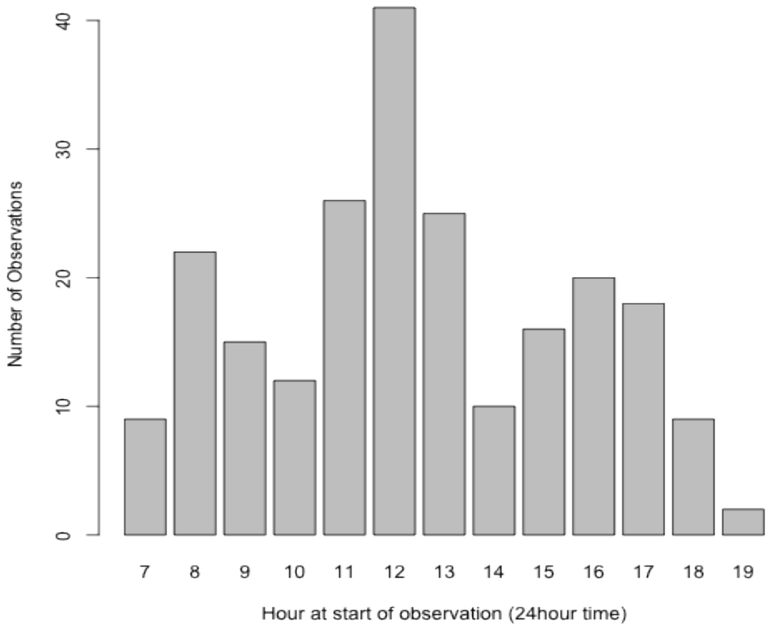

Figure 1: Distribution of brolga observations throughout the day.

3 Home range technical methodology

3.1 Home range maps

The home range extent maps and areas below are calculated using standard kernel estimation techniques. Kernel area estimation has been a tenet of areal studies for over a century and has been extensively applied in areas such as hydrodynamics and home range studies (e.g. Worton, 1989).

Spatial utilisation is described by a probability density function, which is built up by overlaying individual, 'smoothed' observations (Figure 2). The kernel form used for these analyses is a Gaussian kernel.

The influence of a single observation point on the overall density function is determined by the smoothing parameter (or bandwidth).

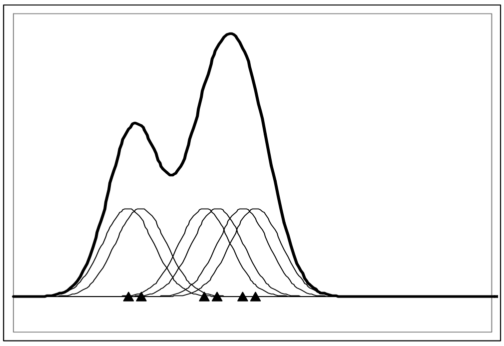

Figure 2: Schematic showing how individual data points are smoothed and combined to create a probability density map of location.

If sufficient data is available, the smoothing parameter can be chosen by an optimisation approach (e.g. least squares cross validation (LSCV)). Infrequent translocations (i.e where the nest is a clear focal point or the data set is small) can cause LSCV to become unstable, in which a heuristic attributed to Silverman (1986) can be applied to generate a meaningful and stable estimate of this parameter.

3.2 Asymptotic analysis

The estimated home range area will vary initially as data points are added. As the number of observations increase, the estimated home range will vary less in response to small data changes. An asymptote analysis recalculates the home range area for additional observation.

To do this, the observations were sorted chronologically and the home range area (90% probability level) was calculated using the first 10 observations. The remaining data-points were added one-by-one and the home range re-estimated. The resulting curve was used to assess whether sufficient data has been obtained.

3.3 Radius of containment

Ultimately, the brolga movement data will be used to inform risk assessment and mitigation for a wind farm. To enable this, we wish to use the data to inform a potential buffer zone around brolga nest sites. The radius of containment measure converts the complexity (directionality) of the measured home range into an equivalent circular buffer of radius *R.* Technically, the radius of containment at some level (e.g. 95%) is defined as the radius of a circle containing the same volume as the cumulative distribution function to that level.

We set the nest to be located at the origin of the buffer, at *r=0.*

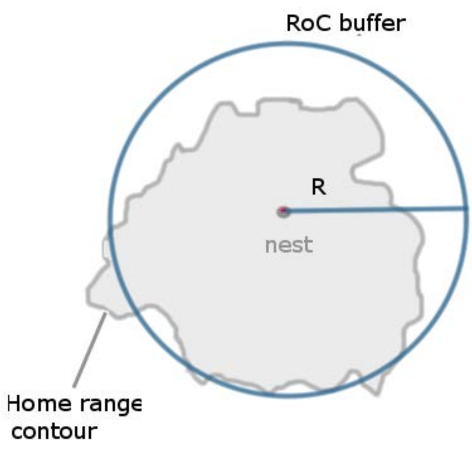

Figure 3: Representation of radius of containment and home range area.

4 Home range results

4.1 Asymptote analysis

To establish the robustness of the home range estimates an asymptote analysis was conducted. The results are shown in Figure 4. There were too few movements for an asymptotic analysis of nest two.

These curves hold information not only about the Home range, but as the data is chronological also show behavioural changes. It is not uncommon to be able to match behavioural changes (such as brooding to fledging, or active brooding to egg failure) for a pair to step changes in the charts.

Nests 4 through 7 show reasonably stable home ranges (though the small number of observations does invoke caution).

Nest 4 (chick present from start of observations) shows an asymptote towards a stable home range value. The final few observations had the brolgas clearly foraging a lot further from the nest site (presumably just before the site was abandoned). Nests 6 and 8 show a stable home range that does not grow or decline considerably with additional data. However, nest 6 should be treated with caution due to the small amount of data. The large jump in home range area for the brolgas at nest 5 occurs just after the appearance of a chick, and clearly delineates the two breeding stages.

Nest 7 and 9 both had one bird on the nest at each observation, and the other moving nearby. The roaming bird at nest 7 was observed most frequently at the beginning of observations, and was often not located at later visits, which is why the estimated home range decreases over time. It is therefore possible that this home range is artificially small due to detectability issues of the second animal.

Although nest 9 did not hatch a chick, the home range area continued to grow throughout the observation period. Most observations recorded the non-nesting brolga in the vicinity and the data suggests that these movements tended away from the nest over time.

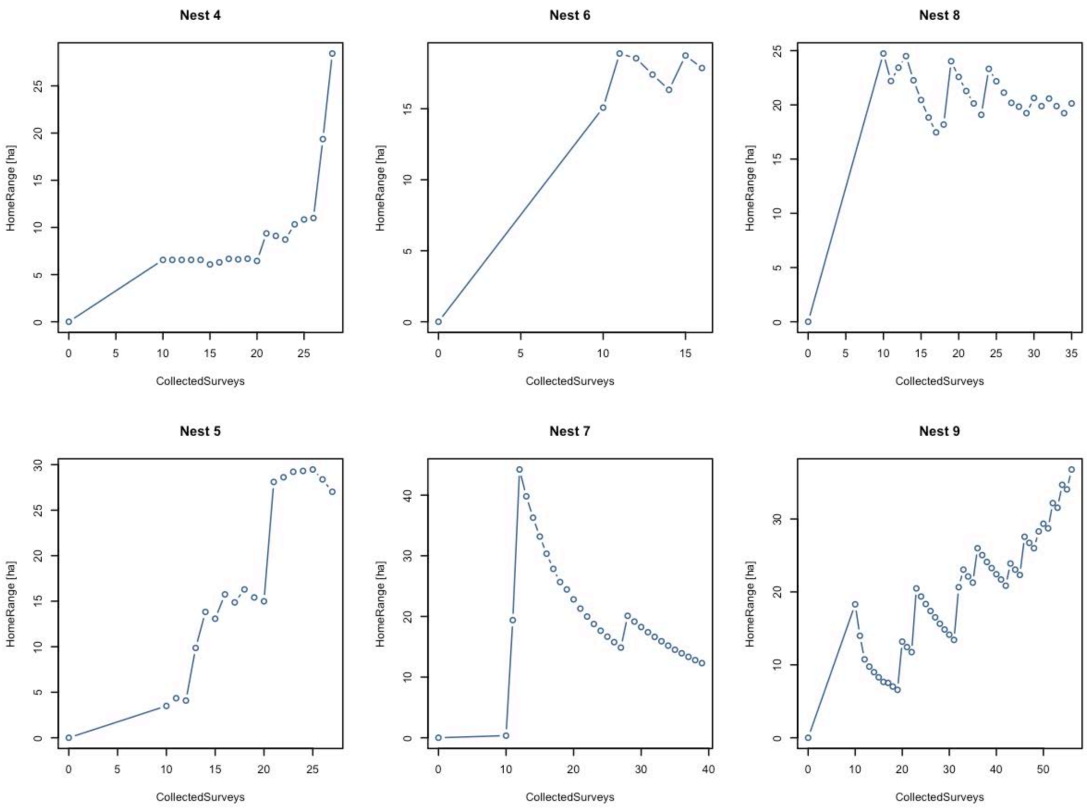

Figure 4: The dependence of the home range area (90% probability level) on the number of data points included in the analysis.

4.2 Home range area

The percentiles of the home range for each nest were calculated using the kernel methods outlined above. Figure 5 shows the utilisation map and Table 2 summarises the area contained at different contour levels. To interpret these, note that 99% of observations of a pair at a given nest are expected to lie in the area contained by the 99% contour.

Technical note: The kernel analysis, unlike Minimum Convex Polygon (MCP), is a probabilistic representation of the animal locations. Therefore, when using Gaussian-type kernels the 100% home range percentile is practically meaningless (mathematically it tends to infinity). As such we only report to 99% confidence level.

Nest ID	50% area (ha)	90% area (ha)	95% area (ha)	99% area (ha)	Bandwidth
Nest 2	0.38	1.9	2.73	4.55	26.82
Nest 4	6.08	28.45	38.52	59.75	87.50
Nest 5	8.59	26.99	36.3	57.33	91.22
Nest 6	5.44	17.83	22.10	31.10	67.97
Nest 7	2.52	12.33	18.23	30.74	68.36
Nest 8	3.52	20.13	27.05	40.69	64.68
Nest 9	4.98	36.82	50.11	76.33	83.23
Combined	4.08	34.89	52.34	80.09	63.83

Table 2: Home range area containing 50%, 90%, 95% and 99% of the home range. The kernel bandwidth for each pair is also recorded.

For each pair the activity is strongly centred on the nest. Nests four and five (the two nests with chicks) cover more area than nests 6-8. Nest 9 is somewhat of an outlier, as discussed above. The home range for nest 9 was largest, though no chick was observed. It has been included in the combined set, nonetheless.

The average home range reported in Table 2 and Figure 6 was calculated by translocating all the data to a common, arbitrary nest location. Based on these observations, one expects to find breeding brolgas within an 80ha area surrounding the nest (to 99% confidence).

The asymptotic analysis suggests that the brolgas at nest 9 have a different behaviour to the other pairs. However, it is representative of the behaviour during this period, and has been retained in the analysis. A biologist/ecologist may make an argument for excising the nest from future analysis. However, it is not wildly different to nest 4 or 5. Such a decision would be made on ecological grounds.

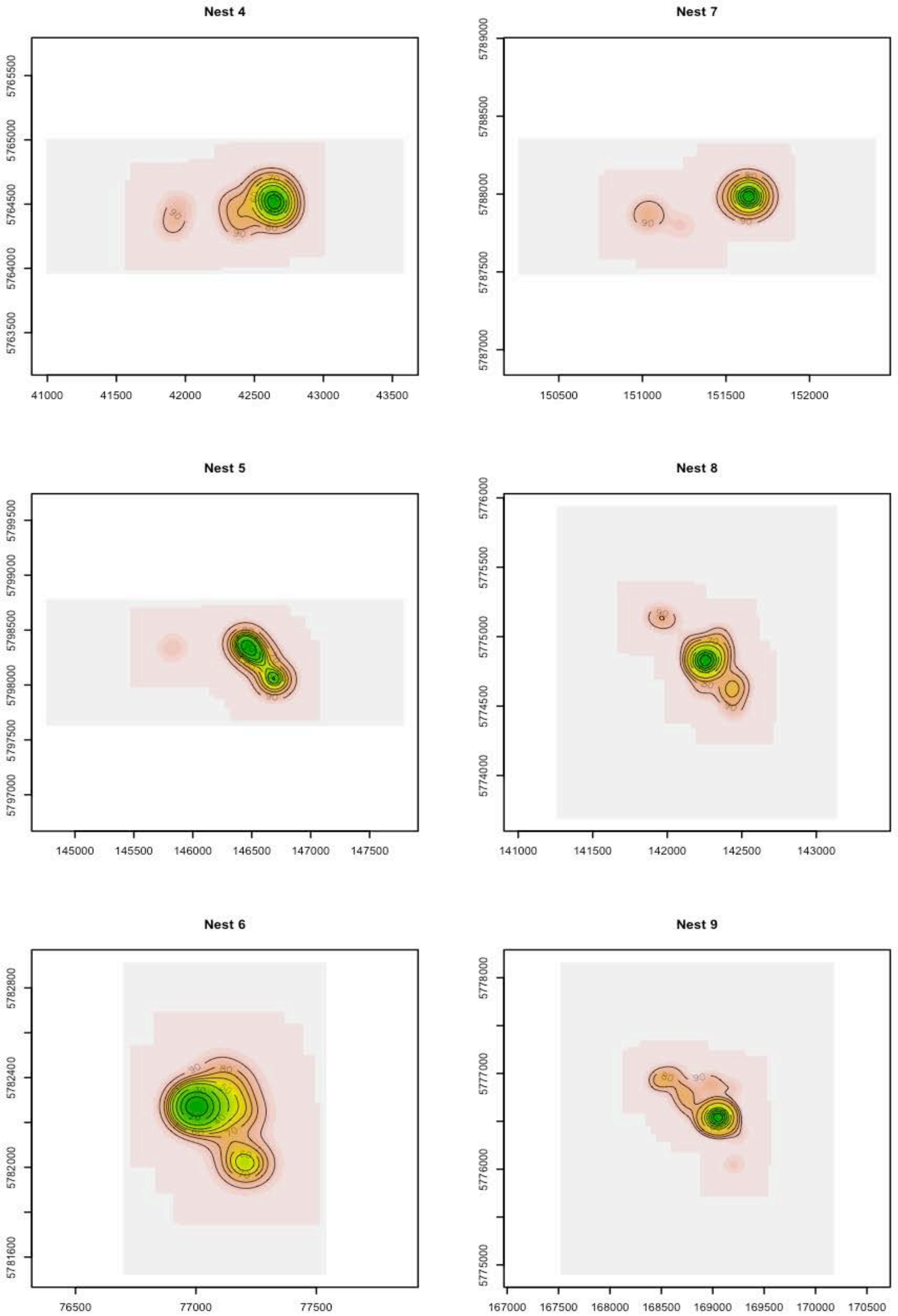

Figure 5: Home range of individual pairs, with probability contours. The axes are Easting and Northing, both in metres. Numbers on contours refer to home range percentile.

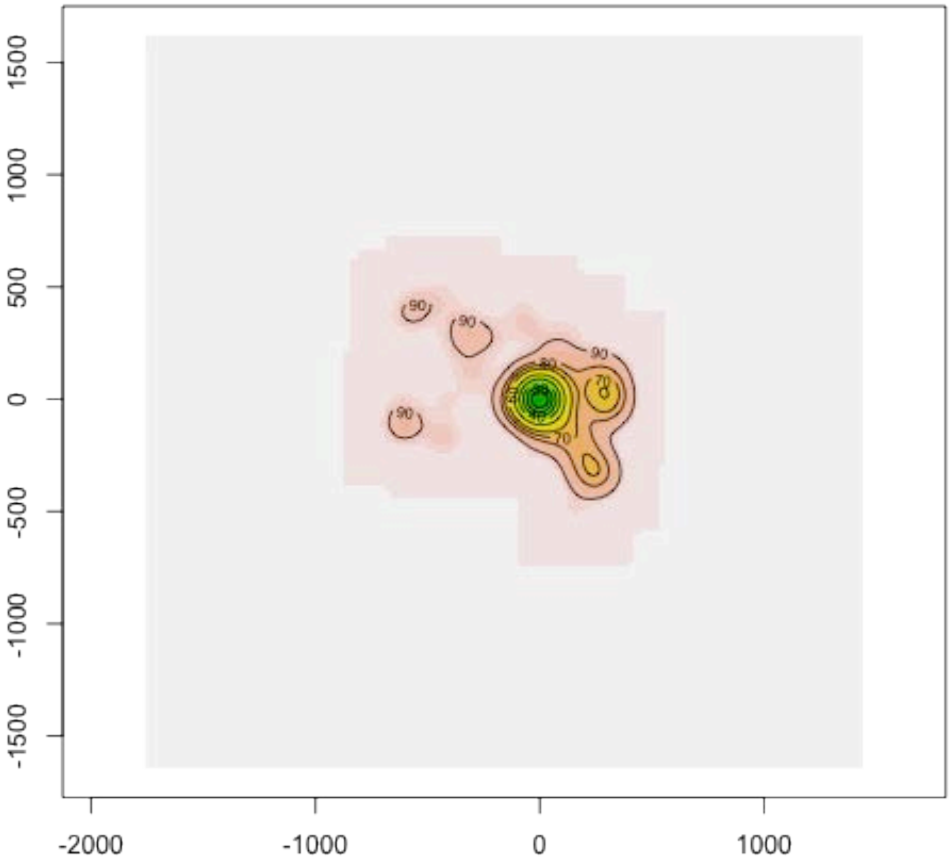

Figure 6: Combined home range, using all data. The axes are measured in metres from the nest. Numbers on contours refer to home range percentile.

4.3 Indicative buffers using radius of containment

The home range areas were converted to equivalent circles centred on each nest. The percentile values of these radii are given in Table 3. Based on the combined data, we would expect to find nesting brolgas within 680m from their nest 99% of the time. Based on the largest individual home range, this radius increases to around 770m.

This translates to a buffer of 145 – 190 ha. This circular area is, by construction, larger than the more complex home ranges in the previous section.

Nest ID	50% (m)	75%(m)	90%(m)	95%(m)	99%(m)
Nest 2*	34	52	86	124	124
Nest 4	296	366	428	466	526
Nest 5	207	382	495	559	651
Nest 6	136	240	333	377	440
Nest 7	89	134	321	564	564
Nest 8	105	191	330	404	494
Nest 9	125	234	493	636	766
Combined	114	262	405	497	679

*Table 3: Radius of containment at key percentage levels for each nest individually and combined. *Nest 2 should be treated with caution due to very low data counts.*

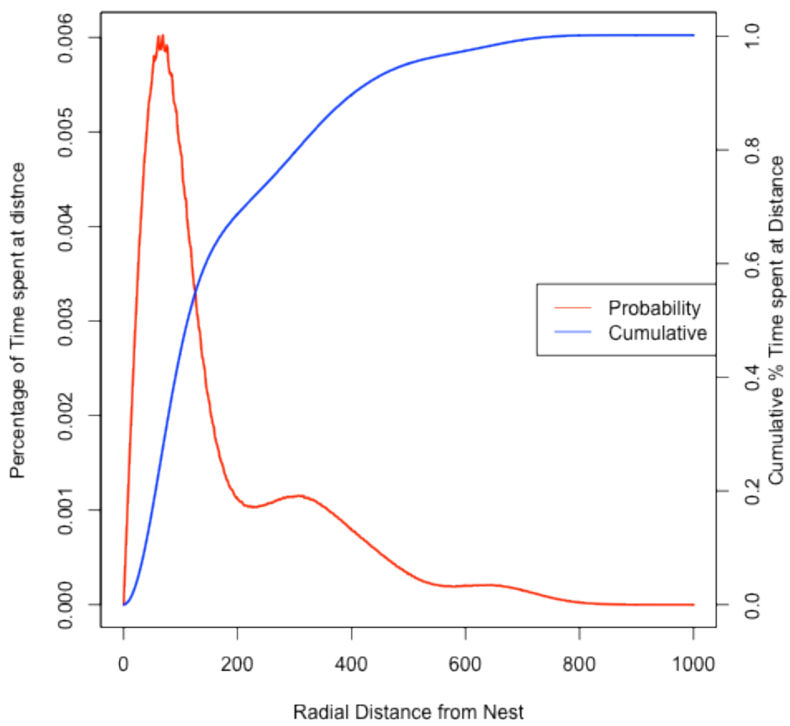

Figure 7: Radius of containment versus distance from nest, all data combined.

5 Discussion

Despite the logistical limitations on the data provided, the home range areas calculated provide information to guide potential buffers around breeding sites. The relatively small size of the nest 2 area should be treated with extreme caution, as it derives from very few movements and is not asymptotically stable. It is only included for completeness.

All home range activity is highest around the nest, and (with the exception of nest 9) brolgas with chicks tend to also record larger areas of activity. When the data is combined and converted into a circular buffer, centred on the nest, it suggests that brolgas are found within 680m of the nest (to 99% confidence).

Overall, this data is suitable as an initial assessment of overall home range behaviour and size, but care must be taken due to the variability and size of the data set. In particular, we recommend that these results be compared against other available streams of evidence (other data or results) to ensure a robust determination of home range areas.

6 References & Further Reading

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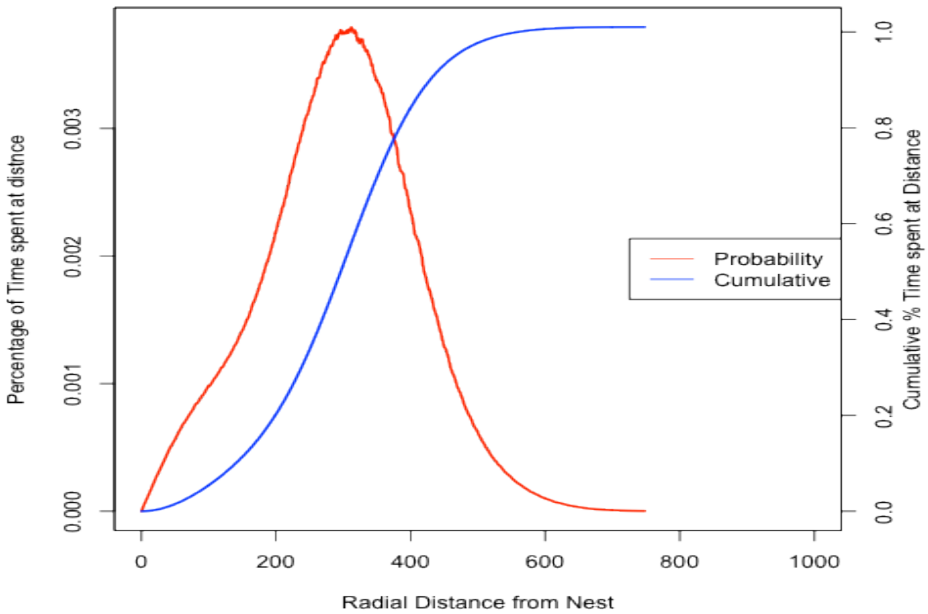
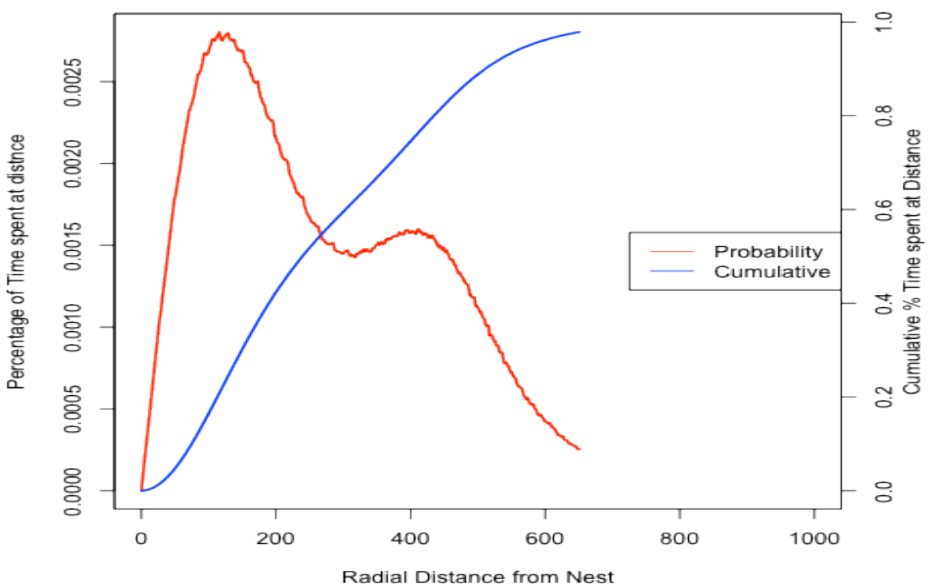
Appendix A Home range results by nest

This appendix shows a summary of the radius of containment buffers from nest 4 to 9.

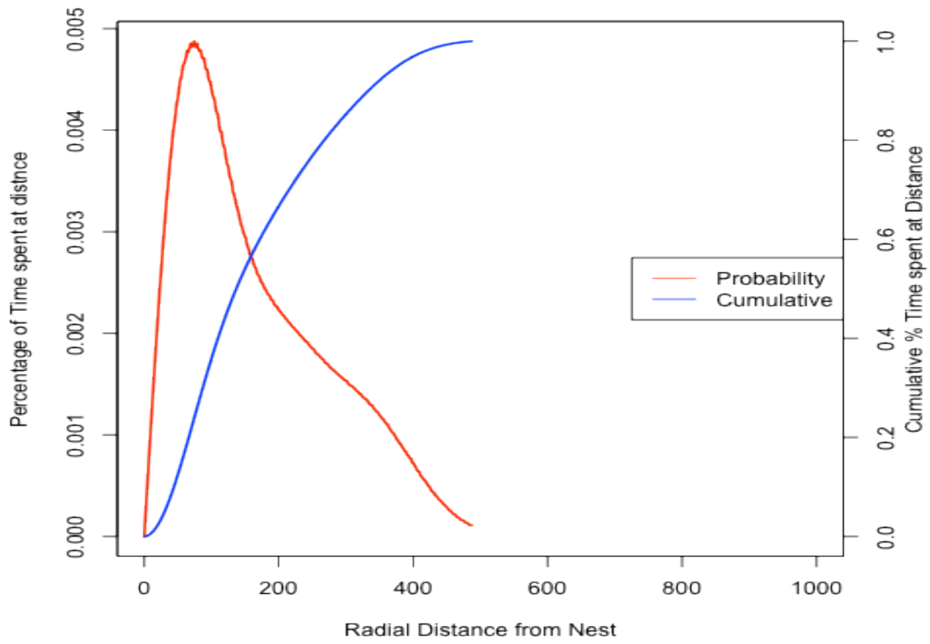
A.1 Nest 4 – Radius of Containment



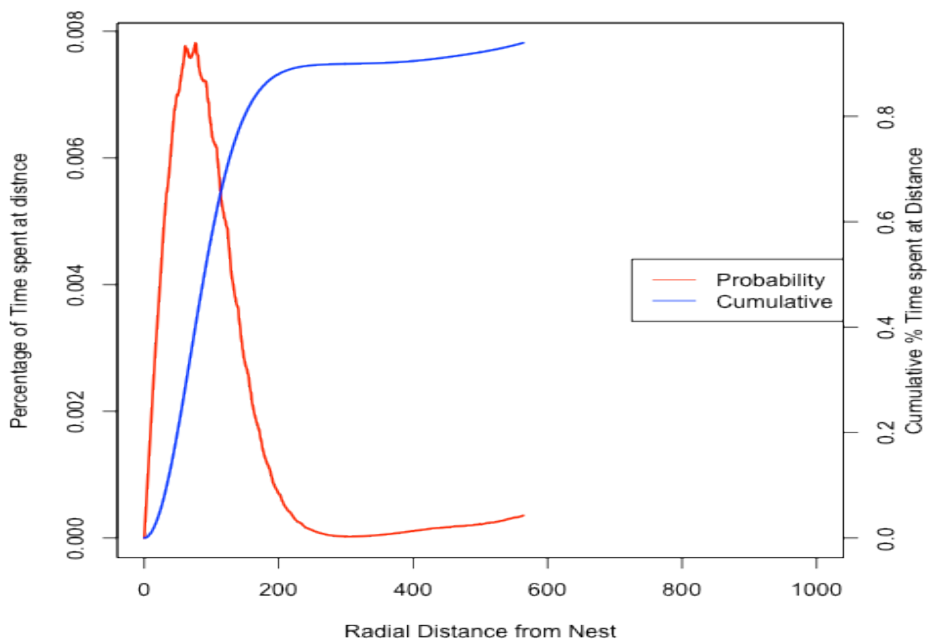
A.2 Nest 5 – Radius of Containment



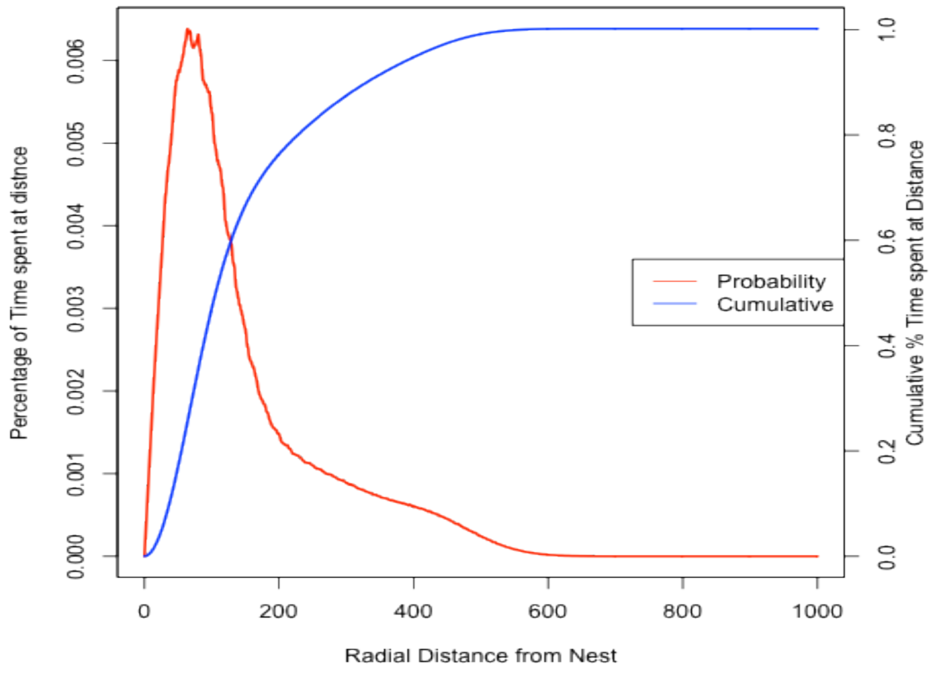
A.3 Nest 6 – Radius of Containment



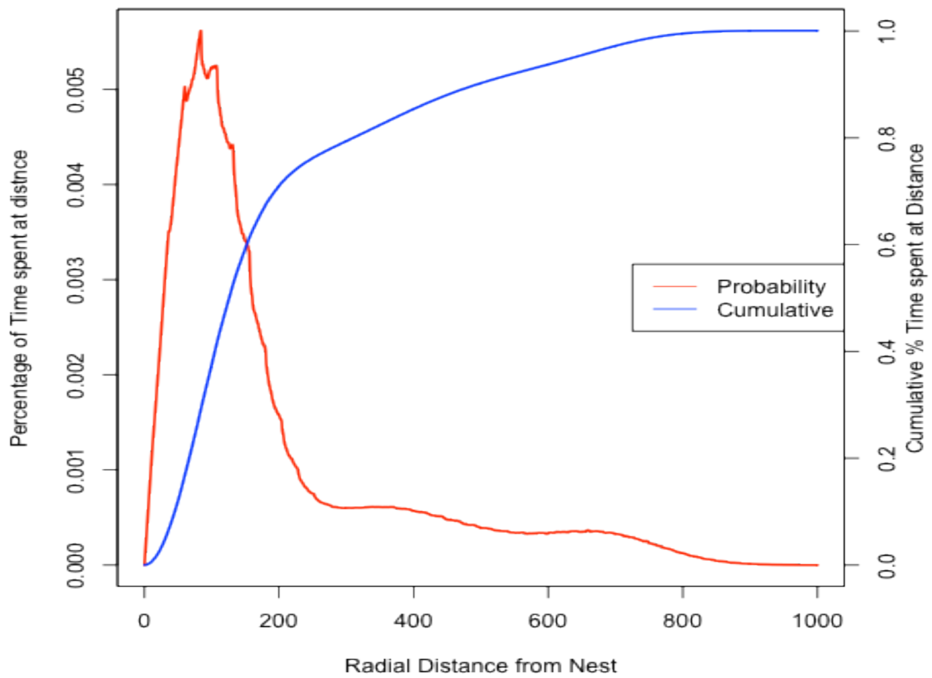
A.4 Nest 7 – Radius of Containment



A.5 Nest 8 – Radius of Containment



A.6 Nest 9 – Radius of Containment



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