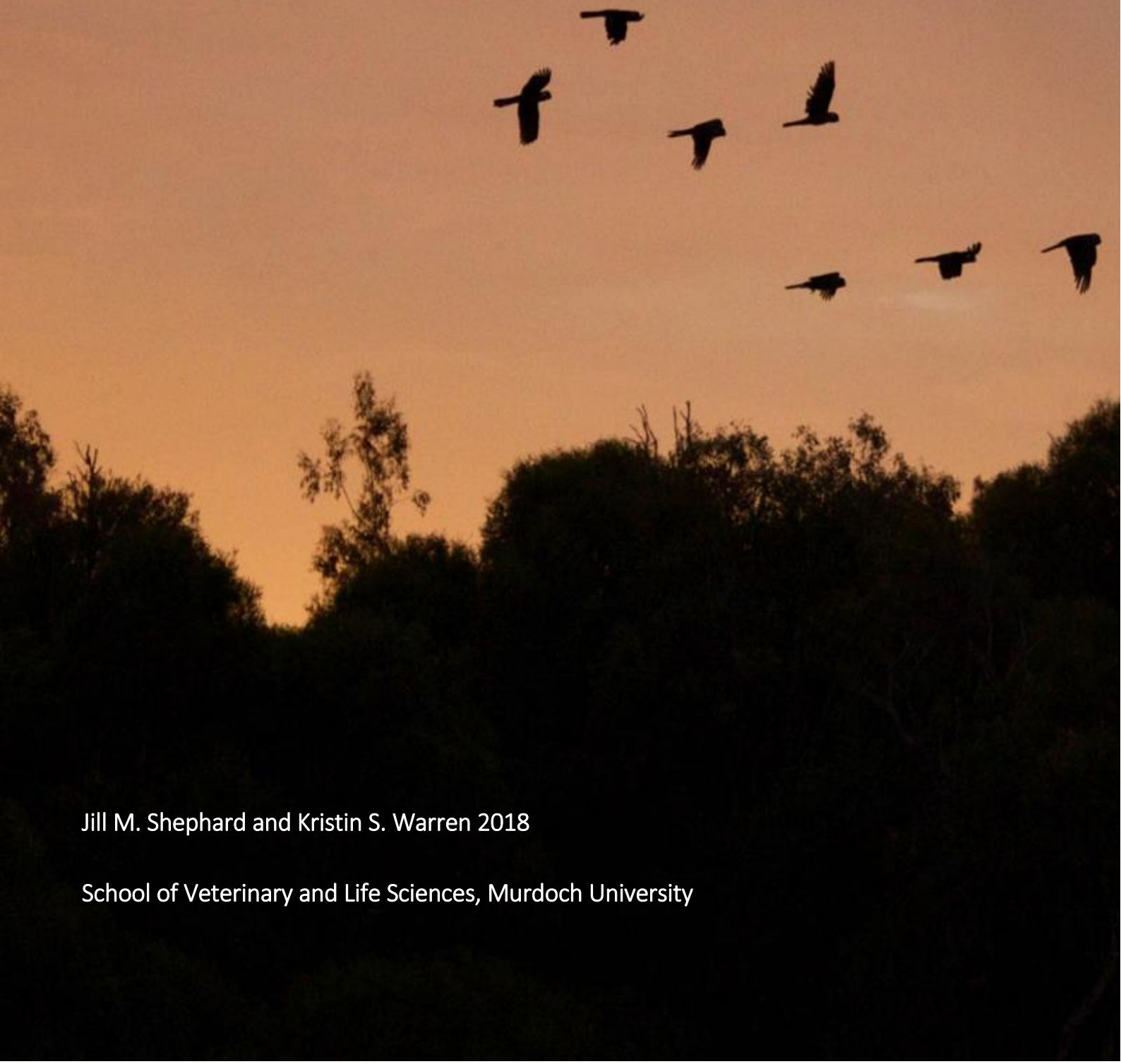
The Potential Role of the Forest Product Commission's Midwest Pine Plantations as a Food Resource for Carnaby's Cockatoo: A Concept Study using GPS and Satellite Tag Data

A report for the Forest Products Commission – Western Australia



Jill M. Shephard and Kristin S. Warren 2018

School of Veterinary and Life Sciences, Murdoch University

Suggested Citation:

Shephard, J.M. and Warren, K.S. 2018. The Potential Role of the Forest Product Commission's Midwest Pine Plantations as a Food Resource for Carnaby's Cockatoo: A Concept Study using GPS and Satellite Tag Data. Report for The Forest Products Commission, Western Australia.

Ethics and Permit Statement:

All tracking took place with approval of the Western Australian Department of Biodiversity, Conservation and Attractions under permit number: SF010448; and with Murdoch University Animal Ethics permit RW2768/15 and Australian Bird and Bat Banding Scheme (ABBBS) Banding Authority Number 1862.

Acknowledgements:

We gratefully acknowledge the financial support and in-kind assistance provided by Newmont Boddington Gold, South 32, PTI Architecture, The Department of Biodiversity, Conservation and Attractions WA, Perth Zoo and Kaarakin Black Cockatoo Conservation Centre in supporting the GPS and Satellite tracking work used in this report. Thank you to Willem Bouten for oversight of the UvA-BiTS tracking system, and to Karen Riley for endless hours in the field downloading data and completing flock follows.

December 2018

Cover photograph by Georgia Kerr

Contents

Definitions

PPCP	Perth-Peel Coastal Plain
SCP	Swan Coastal Plain
GPY	Gnangara-Pinjar-Yanchep Pine Plantations
FPC	Forest Products Commission
GPS tag	Geographic Positioning System tracking tag
Satellite PTT tag	Satellite Platform Terminal tag
Movement Ecology	The study of the movement of an organism defined as a change in the spatial location of the whole individual in time, and driven by processes that act across multiple spatial and temporal scales.
Daily Movement Distance	The daily distance in metres or kilometres that an organism moves in a single day. This may be unidirectional or as a 'round trip' if the organism is moving within a home range.
Ranging Movement	A movement that exceeds the normal daily distance. It may be linked to a range shift but not a migratory movement.
Migratory Movement	A long distance movement that exceeds normal daily distance and may be seasonally linked to movement to a breeding area.
Breeding Area	Area in which breeding Carnaby's cockatoos are resident until after their young fledge.
R	A programming language and free software environment for statistical computing and graphics supported by the R Foundation for Statistical Computing.
BCPA	Behavioural Change Point Analysis.

Summary and Key Outcomes

The Gnangara-Pinjar-Yanchep (GPY) pine plantations play an important role supporting populations of Carnaby's cockatoo on the Perth-Peel Coastal Plain (PPCP), however, the potential for other Midwest pine plantations to support PPCP populations remains largely unknown. In this study, we datamine satellite and GPS data collected as part of ongoing movement ecology research by our research group (The Black Cockatoo Conservation Project, Murdoch University) to gain an understanding of Carnaby's cockatoo movement dynamics across the PPCP and specifically to determine if Midwest pine plantations offer an alternative food resource to Carnaby's using the GPY plantations. Key outcomes of this research are:

- Birds using the GPY pine plantations are unlikely to utilise plantations in the Midwest for foraging during the non-breeding season as the distances exceed their daily movement threshold.
- Some populations are using the Midwest plantations but they must be local populations.
- New tracking studies are required to determine if there is seasonal movement of PPCP Carnaby's to or from the Midwest pines, as well as which regional populations are using this food resource.
- Significant flock overlaps occur in the GPY pine plantations.
- The GPY plantations are used for both roosting and foraging in combination with surrounding land within approximately 10km so that birds can also source water.
- Birds in the GPY plantations also forage in local native vegetation throughout the day when moving between the GPY plantations, Yanchep National Park, and other areas with suitable water sources.
- Once the GPY food resource is exhausted, the plantation flocks appear to concentrate their foraging effort in the Yanchep National Park area.
- Flocks partition the landscape on the PPCP.
- Once birds have moved greater than 50km from their non-breeding range, they are likely starting a migratory movement to a breeding ground.
- Birds that moved south to the Myalup and Capel River area, to known or suspected breeding areas, are roosting in pine plantation and foraging in surrounding native habitat.


Photo:Karen Riley

Background and Significance

Carnaby's cockatoo *Calyptorhynchus latirostris* are endemic to south-western Australia, listed as Endangered under Australian Federal law (*Environment Protection and Biodiversity Conservation Act 1999)* and internationally by the IUCN (Birdlife International 2013). At the state level they are specially protected as "fauna that is rare or likely to become extinct" under the Western Australia *Wildlife Conservation Act 1950*.

Carnaby's cockatoo have undergone an estimated 50% decline over the last five decades (Department of Environment and Conservation 2012), including an average annual 5% decline across the Perth-Peel Coastal Plain (PPCP) over the last nine years (Peck et al. 2018). Overall this has contributed to a suggested 30% range contraction (Department of Environment and Conservation 2012), and significant loss of breeding populations (Saunders et al. 1985, Saunders 1986, 1990). Threats to the species' survivorship are well documented, and include habitat loss and modification, urban and industrial expansion, disease, displacement by competing species, and climate shifts (Johnstone and Kirkby 2008, Johnstone et al. 2013a, b, Lee et al. 2013). These threatening processes are exacerbated by the rapidly increasing urban and industrial development in the Perth and Peel regions and the south-west of Western Australia (Department of Environment and Conservation 2012). Perth's human population is projected to nearly double to 3.5 million by 2050 (Western Australian Planning Commission 2010), emphasising the need to understand flock movements and habitat use, and identify critical feeding and breeding sites, which still remain largely unknown despite early attempts using direct observation (Saunders et al. 1985, Saunders 1986, 1990, Saunders and Ingram 1998).

The Gnangara-Pinjar-Yanchep (GPY) pine plantations provide significant feeding and roosting resources for Carnaby's cockatoo. In the 2018 Great Cocky Count, 180 roost sites were surveyed across the PPCP. Surveys in the Gnangara-Pinjar pine plantation accounted for 65% of birds in the total census (Peck et al. 2018). Since 2003/2004, harvesting of the pines has been undertaken at a rate of 800-1500 ha per annum. This land was subsequently left for wilding and native vegetation regrowth, and approximately 360 ha was reestablished with banksia spp. and other native vegetation. Currently 6000 ha of mature pine remains, and between 2012 and 2017, just over 2000 ha of pines were replanted. In light of historic and continued clearing of the GPY plantations (Government of Western Australia 2015) it is useful to determine if Forest Product Commission (FPC) managed Midwest pine plantations

have the potential to compensate for resource bottlenecks presented by the removal of the GPY plantations, particularly in the critical 2019-2024 lag period before wilding regrowth may support renewed foraging activity; though notably 18,000 ha of pine wildings are available at different stages of maturity. The Midwest plantations are highly dispersed across the landscape, ranging from 0.01 ha to 100 ha blocks; providing scattered and relatively localised but energetically valuable food resources. Their potential to support PPCP populations remains largely unknown (Shah 2006, Finn et al. 2014, Peck et al. 2017, Williams et al. 2017).

Research Aims

Since 2015, the Black Cockatoo research team has successfully deployed 39 satellite and GPS tracked Carnaby's cockatoos across the species' south-west Western Australia distribution, with a specific focus on the urban and peri-urban landscape mosaic, and northern pine plantations of the PPCP. Of these release birds, 14 supplied movement tracks across the study region. We analysed these data to determine the likelihood that Midwest plantations may be a viable food resource. Given the dispersed nature of the plantations in the landscape, their use by birds from the PPCP is likely to be dependent on the distance of plantations from the PPCP, the extent of connectivity afforded by native vegetation corridors, and the productivity and food resources provided by the pine plantations. We specifically aimed to address the following:

1. Understand and quantify bird movement across the PPCP.
2. Determine the relative importance of vegetation corridors on movement.
3. Determine the distance of FPC plantations from known PPCP Carnaby's cockatoo flocks and roost locations within the GPY.
4. Gain insight into the distribution of native/other vegetation corridors and water availability adjacent to Midwest plantation lots.
5. Aim to prioritise existing plantations as a food resource based on movement statistics and other identified values (e.g. water availability, vegetation corridors).

Methods

Study birds and tag attachment method

Birds used in this study were wild birds injured on the Swan Coastal Plain (SCP) and admitted to the Perth Zoo Veterinary Department for assessment and primary care. The birds were transferred to Kaarakin Black Cockatoo Conservation Centre for rehabilitation and to undergo flight conditioning, until they were determined fit for release by the Western Australian Department of Biodiversity, Conservation and Attractions. The birds were released in 2016 and 2018 at three locations on the SCP in four group releases (Table 1). Additional untagged birds were included in the release groups. We chose release locations on the basis that they had a resident night roosting flock at the time of release. A minimum of four tagged birds were included in each release group.

Carnaby's cockatoos were tagged with a separate satellite and GPS unit using a custom double mounting procedure (Yeap et al. 2017). Of the 14 birds tagged, four removed their GPS tag before release and so carried a satellite tag only.

The Telonics ARGOS Satellite PTT (Platform Transmitter Terminal) tag (TAV-2617) was tail-mounted and weighed 17 g (tag dimensions: 6.43 cm × 2.1 cm × 1 cm; Telonics, Mesa, AZ, USA). The solar GPS tag (Bouten et al. 2013; UvA-BiTS, Amsterdam, The Netherlands; 2CDSe, tag dimensions: 52 mm × 22 mm × 9 mm) was back-mounted and weighed 7.5 g. We attached the satellite tags to the two central tail feathers using braided nylon fishing line (Fireline®, Berkley®, Spirit Lake, IA, USA). The GPS tags were joined to a mounting plate attached with cloth tape to approximately four feathers just below the shoulder joints. The GPS tags were tied to the mounting plate using braided nylon fishing line (Fireline®, Berkley®), and reinforced with glue (Selleys Ultra Repair Glue; Selleys, Padstow, NSW, Australia) (Fig. 1). The combined weight of the tags was less than 5% of the birds body mass, and meets ethical requirements (Cochran 1980, Kenward 2001). All tag attachment was performed under anaesthesia.

In addition each bird was fitted with a metal numbered ABBBS (Australian Bird and Bat Banding Scheme) band on the right leg, and a unique colour combination of two metal leg bands on the left leg, to facilitate identification in the field. Some birds were also tail painted to assist with field identification in the short term (Fig.1).

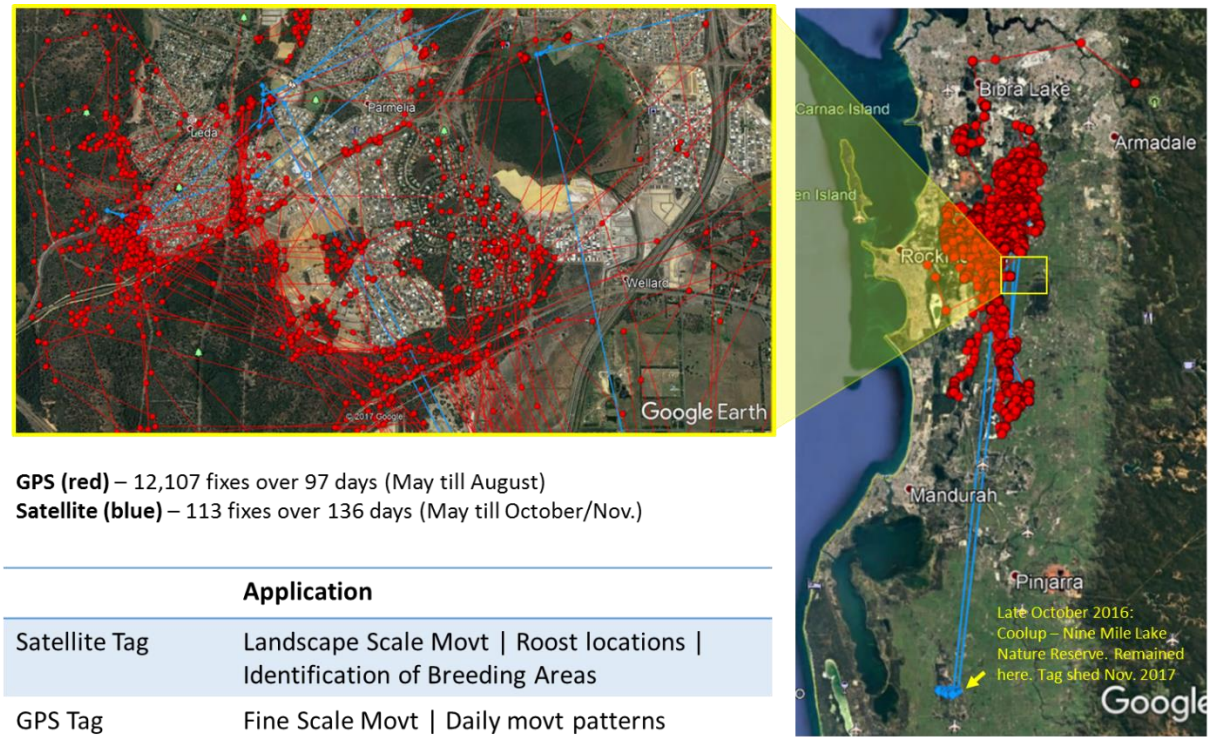
Fig.1 - a) Tag attachment in Carnaby's cockatoo is performed under anaesthesia; b) the satellite tag is attached to the underside of the two central tail feathers; c) the GPS tag is attached to a back plate that is taped to a number of feathers on the back; d) birds are fitted with a unique colour coded two band combination on the left leg and a ABBBS metal band (not shown) on the right leg (photo credit: Keith Lightbody); e) some birds released on the Swan Coastal Plain had their tail feathers painted to assist with identification in the field in the first few weeks after release.

Data retrieval and tag programming

Data were collected via the ARGOS satellite based positioning system and downloaded from the Telonics ARGOS satellite tag using the web-based user interface (ARGOS CLS System 2018; https://argos-system.cls.fr/argos-cwi2/login.html). ARGOS data are classified to location accuracy classes (LC): 3, 2, 1, 0 and A, B, Z. Location classes 3 to 1 are accurate to between < 250m to 1500m, LC0 is > 1500m, LC A and B have no accuracy estimations, and LC Z is considered invalid (CLS 2007-2014). We only used LC 2 and 3 locations. We programmed the satellite tag schedule to communicate in blocks of four hours on either mornings (0600–1000) or nights (2000–2400). Specifically we used LC 3 locations to locate tagged birds at night roosts to facilitate the manual download of high-resolution GPS data to a base station. The morning communication block allowed for field-based flock follows and visual observation when the birds would likely be foraging. On average, we collected up to three LC 2 or 3 location fixes during communication periods. We programmed the GPS tag to record location fixes every 30 minutes (accuracy ±20 m) during the night and every 2.5–15 minutes during the day depending on solar battery charge. This difference in data resolution was expected (Fig. 2). The tags had different functions in this study. The satellite tag was programmed to capture landscape scale movement, roost locations, and the identification of breeding areas by using a conservative programming schedule that maximised tag life, as well as identified roost locations to facilitate GPS data download. The GPS data captured fine-scale movement at a resolution appropriate to current analysis methods. The GPS data were post-processed using the University of Amsterdam Bird Tracking System (UvA-BiTS) Virtual Lab and downloaded from the Virtual Lab portal (www.UvABiTS.nl/virtual-lab; Bouten et al. 2013) for analysis.

Data analysis

Satellite and GPS data were checked for errors with summary plots for distance, time and duration between relocations using the 'adehabitatLT' package (Calenge 2006). Daily movement statistics were calculated for each bird and data were coded to day and night using the 'sunriset' method in the 'Maptools' package (Bivand and Lewin-Koh 2018). Night locations were used to locate night roosts across the PPCP.



GPS (red) – 12,107 fixes over 97 days (May till August)
Satellite (blue) – 113 fixes over 136 days (May till October/Nov.)

	Application
Satellite Tag	Landscape Scale Movt | Roost locations | Identification of Breeding Areas
GPS Tag	Fine Scale Movt | Daily movt patterns Suitable for current analysis methods

Fig. 2 - The difference in data resolution for a Carnaby's cockatoo tagged with both a satellite tag (blue tracks) and GPS tag (red tracks). The data density is many orders of magnitude greater in the GPS download, which captures a detailed picture of fine scale movement. The longer tracking period afforded by the satellite tag has captured the start of a migratory movement south. The tail feathers in this bird moulted in November and it is likely this bird continued further south to breed.

We used behavioural change point analysis (BCPA) in the 'bcpa' package (Gurarie et al. 2009, Gurarie 2014), following the protocol of Rycken et al. (2018), to confirm that released GPS tagged birds were moving with a flock and therefore that individual bird movement was representative of flock movement. This had the added advantage of allowing us to quantify the number of flocks tracked, and their spatial partitioning and distribution.

We combined data across GPS tags to calculate population scale revisitation rates for Gnangara release birds released in the Pinjar plantation using the package 'recurse' (Bracis et al. 2018). We used this method to identify preferred roost, foraging and watering sites as well as movement corridors related to movement in and out of the GPY plantation region. The method works by taking a circle of user specified radius and moving it along the movement trajectory (Bracis et al. 2018). Movement into and out of the circle counts as a single visit. Circles of high use, that is, areas of high revisitation, have many independent visits. The

revisitation rate can be manipulated by changing the size of the circle. Therefore, the circle needs to be both ecologically appropriate to the species, and appropriate to the activity targeted. For example, a small circle may capture the location of a foraging site, but may be too small to capture a night roost; which for Carnaby's cockatoos may be as large as $1km^2$ depending on flock size (Glossop et al. 2011). We used a circle radius of 500m for all data considered together and the night data set. The day data were analysed at two scales. A circle radius of 500m was used to capture movement corridors, and a circle radius of 100m was used to capture foraging and drinking activity. In addition, we applied a threshold of 60 minutes to the revisit data. This allowed a bird to leave the circle and return within a 60-minute period without the revisit being counted. This accounted for small excursions that may be due to flushing or disturbance. It was considered that a bird that had been absent for longer than 60 minutes had left the area or had time to take part in another activity elsewhere.

Using revisitation rates, we also calculated activity and residence time in a 24 hour period (circle radius 500 m; threshold 60 minutes) using all data to identify periods of high and low activity representing foraging and day or night roosting periods.

Based on the number of sites identified by the recurse analysis with high visitation rates, we performed a cluster analysis using the 'fanny' method in the R 'cluster' package (Maechler et al. 2018) specifying three clusters for night data and four clusters for day data. We then calculated the centroid of these clusters to calculate distances to the Midwest pine plantations. We obtained the pine plantation data (Forest Products Commission Plantations (FPC-001)) from DataWA <https://services.slip.wa.gov.au/public/rest/services/SLIP_Public_Services/Environment_WFS/MapServer/7> and subset the data to extract only *Pinus pinaster* and *P. radiata* plantations between Latitudes -30.0 to -33.5 and Longitude <119.0. We calculated a centroid for each plantation polygon in ArcGIS 10.5 and then exported the data for further analysis in R. Polygons belonging to the Yanchep, Pinjar, and Gnangara plantations were removed, and pairwise distances between night roost centroids and plantation centroids were calculated using the R package 'fossil' (Vavrek 2011). For visualisation purposes, we allocated distances to classes based on movement statistics derived in this study where classes were: 1) ≤ 20km (maximum daily linear movement); 2) >20 ≤ 50km (ranging movement); 3) >50 ≤ 100km (migration movement); 4) > 100km (migration movement).

For other regions on the PPCP, or in the mid-west or south-west, movement corridors and the relative importance of vegetation corridors were identified through map visualisation at the landscape scale. Except where noted, all data processing, analysis and map production was conducted in R (version 3.5.1; R Core Team 2017) using RStudio (version 1.0.153; RStudio Team 2016).

Results

Across all releases, 14 birds were satellite tracked for 1,479 days, from which 413 days of data were collected. This difference was due to the programme schedule, which was designed to identify night roost locations and to maximise battery life. Ten of these birds were also GPS tracked over 285 days and collected 278 days of data (Table 1). Missed days were a result of poor weather, which caused the solar battery level to deplete. Under these conditions the tag 'goes to sleep' until the battery level is recharged. The satellite tags collected 1,100 LC 2 or LC 3 location class fixes; by comparison 32,852 GPS locations were received at 5-20 minute intervals. Satellite tagged birds were tracked for an average 101 days (range: 2 to 286 days), and GPS tagged birds were tracked for an average 29 days (range: 1 to 97 days). Average daily movement distances were not calculated for the satellite data as points were only collected in the morning or at night. Average daily movement for GPS tagged birds was 16 km, but ranged from 3 km to 31.5 km. This described return movement to a roost location following daily foraging activity. Several birds (CC1 and CC4) moved just over 50km (Table 1), but these were related to ranging movements where the flock shifted roost locations. In one of these shifts, the ranging movement was due to a flock relocation to the GPY region. Overall, the satellite data described 2,357km of movement and the GPS data described 6,365km of movement (Fig. 3). In addition, the satellite tracking showed migratory movement by four birds that moved either south or east to breeding areas (Fig. 3).

Flight speed was very low for this species, with 88% of all daytime relocations occurring at less than or equal to 1m/s. At this speed the average distance travelled was 74m between relocations (the distance between 2 consecutive GPS points) which could take up to an average nine minutes; suggesting that birds were either resting, day roosting or foraging within a limited area for a large part of the day, or moving through the landscape relatively slowly most of the time.

Table 1 - Track and Daily movement summaries for Carnaby's cockatoos on the Perth-Peel Coastal Plain. Birds that were double tagged have both Satellite and GPS Data. Satellite data reports LC 2 and LC 3 relocations only. The number of data days for satellite data reflects the programming schedule, which was designed to capture overnight roost locations to facilitate GPS download to a mobile base station. The satellite tags were also turned off for long periods to maximise battery life and capture movement over the long-term. See methods for programming schedule. Flock status was determined with Behavioural Change Point Analysis using the methods of Rycken et al. (2018).

ID	Year	Release Site Lat/Long (DD)	Sensor	Tag ID	Flock Status	Start date	End date	No.Reloc	No. days tracked	No. data days	% days data	Distance travelled per day (km) Min.	Max.	Av.	Distance (km)
CC1	2016	Murdoch	Sat	159154		19/05/2016	03/10/2016	113	136	42	31				408.51
		S32.068 E115.83	GPS	2216	Y	19/05/2016	24/08/2016	12107	97	97	100	6.01	55.67	31.47	3084.05
CC2	2016	Murdoch	Sat	159155		19/05/2016	03/09/2016	79	106	36	34				115.85
		S32.068 E115.83	GPS	-	-	-	-	-	-	-	-	-	-	-	-
CC3	2016	Murdoch	Sat	159156		19/05/2016	03/06/2016	44	15	15	100	-	-	-	32.05
		S32.068 E115.83	GPS	-	-	-	-	-	-	-	-	-	-	-	-
CC4	2016	Murdoch	Sat	159157		19/05/2016	01/03/2017	139	286	53	19				533.48
		S32.068 E115.83	GPS	2222	Y	19/05/2016	13/08/2016	14890	86	86	100	1.90	52.95	21.89	1904.26
CC5	2016	Perry Lakes	Sat	159162		21/06/2016	06/11/2016	99	137	40	29				108.87
		S31.946 E115.787	GPS	2258	Y	21/06/2016	04/07/2016	481	12	11	92	0.00	32.26	9.43	103.77
CC6	2016	Perry Lakes	Sat	159163		21/06/2016	09/07/2016	40	20	18	90				38.95
		S31.946 E115.787	GPS	2260	N	21/06/2016	11/07/2016	1208	20	18	90	0.39	26.21	11.53	207.63
CC7	2016	Perry Lakes	Sat	159164		21/06/2016	06/03/2017	121	257	53	21				117.15
		S31.946 E115.787	GPS	2261	Y	21/06/2016	24/07/2016	1277	32	27	84	0.00	24.47	5.57	150.27
CC8	2016	Perry Lakes	Sat	159165		21/06/2016	05/02/2017	126	227	47	21				453.17
		S31.946 E115.787	GPS	2263	Y	21/06/2016	01/07/2016	542	9	9	100	0.08	32.63	12.88	128.77
CC9	2018	Gnangara 1	Sat	166153		08/03/2018	20/04/2018	71	43	24	56				103.67
		S31.533 E115.808	GPS	-	-	-	-	-	-	-	-	-	-	-	-
CC10	2018	Gnangara 1	Sat	166155		08/03/2018	10/03/2018	8	2	3	150				32.62
		S31.533 E115.808	GPS	-	-	-	-	-	-	-	-	-	-	-	-
CC11	2018	Gnangara 1	Sat	166168		08/03/2018	20/03/2018	39	12	12	97				38.19
		S31.533 E115.808	GPS	2328	Y/?	09/03/2018	11/03/2018	367	3	3	100	14.82	27.13	20.28	60.84
CC12	2018	Gnangara 1	Sat	166169		08/03/2018	03/04/2018	59	26	18	69				83.98
		S31.533 E115.808	GPS	2327	Y	08/03/2018	17/03/2018	604	8	8	100	0.06	29.01	15.82	158.19
CC13	2018	Gnangara 2	Sat	163587		22/03/2018	28/03/2018	15	6	6	100				32.27
		S31.537 E115.802	GPS	2330	-	24/03/2018	25/03/2018	44	1	1	100	0.11	6.05	3.08	6.17
CC14	2018	Gnangara 2	Sat	49926		22/03/2018	13/10/2018	147	205	46	22				258.47
		S31.537 E115.802	GPS	2331	Y	22/03/2018	10/04/2018	1332	18	18	100	0.88	49.10	28.06	561.12
						Totals	**Sat**	1100	1478.78	413					2357.25
							GPS	32852	285.81	278					6365.07

Flock partitioning and distribution on the Perth-Peel Coastal Plain

Movement paths suggest that all birds joined different flocks that were spatially distributed across the PPCP (Fig. 3). Seven of the 10 GPS tracked birds were confirmed to join a flock using the BCPA method. One bird (CC11; tag 2328) had insufficient data for analysis. It was

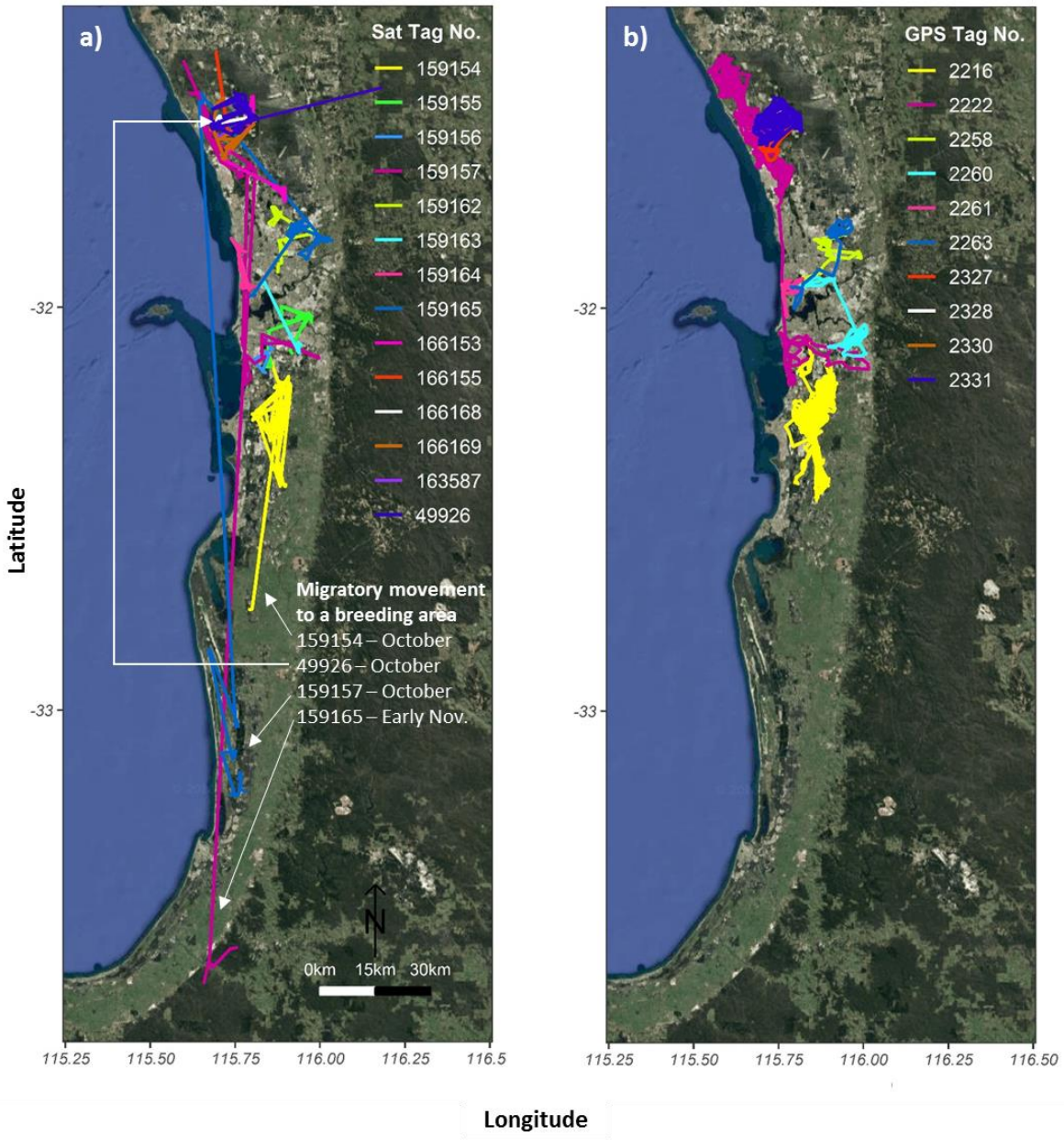


Fig. 3 - Movement tracks of Carnaby's cockatoos Calyptorhynchus latirostris *for a) satellite tagged and b) GPS tagged birds. The colours are the same for birds that were double tagged. For example CC1 (Table 1) carries satellite tag 159154 and GPS tag 2216. The satellite data describes 2,287 km of movement and the GPS data describes 6,365 km of movement. Migratory movement was captured for four satellite tagged birds in October and November. 159154 moulted its tail feathers in October therefore dropping its tag. We do not think the data captured this bird's full movement to the breeding area. Additional information about breeding movements is in the text.*

not clear if CC11, which was part of the first Gnangara release in the Pinjar Plantation (Table 1), integrated based on the BCPA analysis, as it only retained its tag for three days. Several days after it removed its GPS tag however, it was sighted in the vicinity of several hundred birds during a morning flock follow (14/03/2018). Only one bird (CC6) did not join a flock. This bird was readmitted to Karrakin Black Cockatoo Conservation Centre after a period of field monitoring, as its activity suggested it was never likely to integrate.

Flocks appeared to partition the landscape with little overlap (Fig. 3), except in the GPY area where there was clear track overlap between birds that moved north to this region and those in the Gnangara releases. This is covered in detail below. Considering both satellite and GPS data together, the tracking data is representative of up to 14 flocks across the PPCP. As this is only a small sample of all potential flocks on the PPCP, it provides interesting insight into the way flocks partition available resources. Night roost locations also confirm spatial partitioning (Fig. 4). Generally, the longer birds were tracked, the more spatially segregated their roost sites became; although birds released in the same release group shared regionally similar night roost locations at least in the short term.

Movement to breeding areas

Once birds moved greater than 50 km in a day, their tracks continued in a single linear direction that was consistent with migratory movement. Four birds made long distance directed movements, captured with the satellite data, either south or east toward breeding areas (Fig. 5). All birds made this movement in October, which is consistent with known movement to breeding areas. In one case (CC1), the bird appears to have moulted the tag before completing the movement to the breeding area. It was possibly at a stopover site, and was observed with a group of 46 other Carnaby's during a flock follow in November. Both CC4 and CC8 made significantly longer southern movements (180 – 220km) to Myalup and Capel River respectively (Fig. 5b and Fig. 5c). Both were observed roosting in pine plantations with large flocks (30 – 200+ birds), flying in pairs, and actively prospecting for hollows in native vegetation.

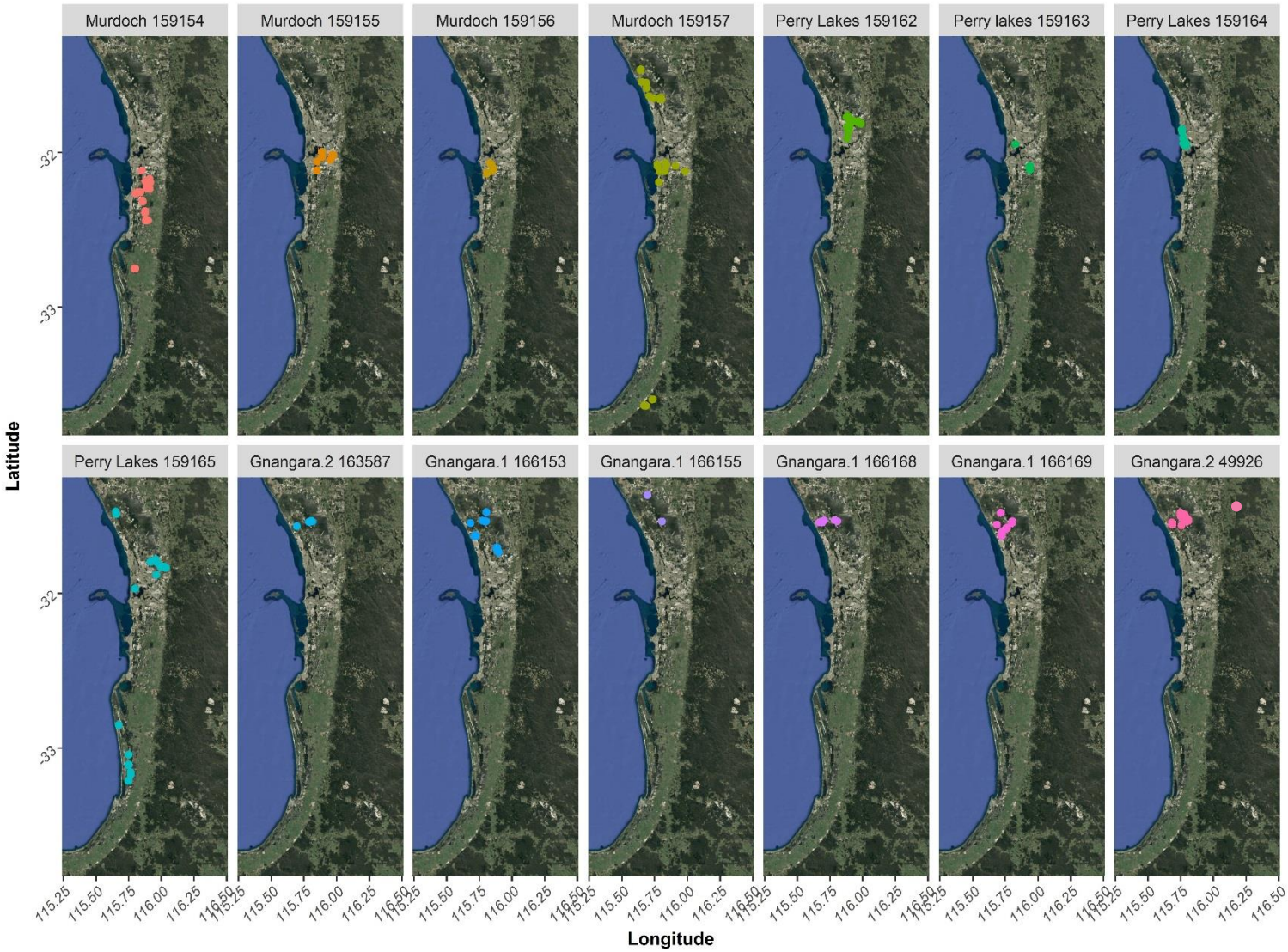


Fig. 4 – Unique night roost locations captured from satellite data for each Carnaby's cockatoo tracked. Release locations precede the tag number. For clarity, only the first confirmed roost location of each night roost for each bird is shown.

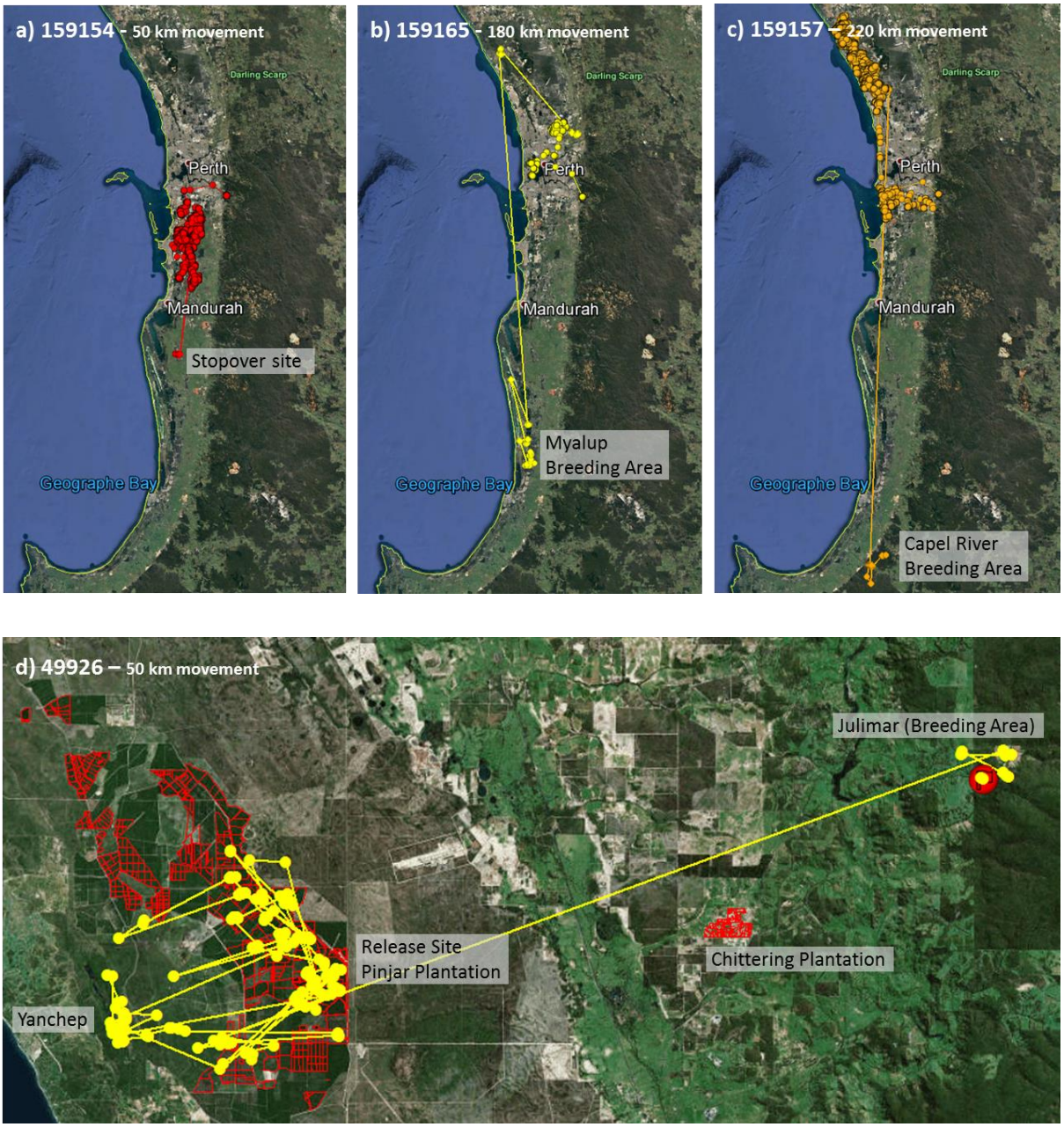


Fig. 5 – Long distance migratory movement in four Carnaby's cockatoos on the Perth-Peel Coastal Plain captured using satellite data. a) CC1 – satellite tag 159154 moulted its tag in the Myalup region. We think this was a stopover site. The bird was observed in a flock of 46 birds which we think moved further south to a breeding site; b) CC8 – satellite tag 159165 moved 180 km south to a breeding area in the Myalup region and was observed roosting in pine blocks with a large flock (200+ birds) and prospecting with a potential mate; c) CC4 – satellite tag 159157 moved the farthest south to the Capel River area. Its movement data shows it making use of both pine blocks and adjacent native vegetation. It was also sighted with a flock of approximately 30 birds that were prospecting hollows and moving in pairs; d) CC14 – satellite tag 49926 was the only tagged bird to move east, to a known breeding area in Julimar National Park. Red polygons show FPC pine plantation blocks from Yanchep, Pinjar and Chittering plantations.

CC14 was the only tagged bird captured moving east; to a known breeding site in Julimar National park (Fig. 5d). This bird flew from Yanchep National Park to Julimar National Park. Due to a planned one-month gap in the satellite tag programming schedule, to maximise battery life, it is not clear whether this was a single movement or made in stages. It is possible that the bird made use of Chittering Pine Plantation during this migration movement.

Movement in Gnangara-Pinjar-Yanchep region

Two releases were made in the Gnangara region at a site in the Pinjar plantations (Table 1, Fig. 6). Six birds were satellite tagged and four of these were double mounted with a GPS tag. The Gnangara releases were not originally planned in the 2018 schedule. These releases were planned for the Boddington region, but we were unable to find reliable flocks to release into, and rather than cancel releases, we relocated to the Gnangara region. Releasing into a flock is an important management strategy as it supports faster flock integration, decreases the potential for predation, and exposes the release birds to local knowledge from the flock regarding foraging, watering and roosting sites. These releases were delayed until March however, and it was not clear if the birds retained tail feathers from the previous year (i.e. had not already moulted out their old tail feathers). Consequently, we were not sure how much data we would capture, as once the tail feathers moulted, the loss of the satellite tag would prevent us from locating the bird to download the GPS data. Despite these challenges, we captured between two and 205 days of satellite data, and between one and 18 days of GPS data. Analysis from the GPS data showed that the four tracked birds likely belonged to two different flocks (Fig. 7a). Specifically, CC12 (tag 2327) and CC14 (tag 2331), which were confirmed as flocked using BCPA, were latitudinally segregated. The early and later segments of their tracks were reversed, with CC14 following a more northerly path during daytime foraging. The distribution of tracks also showed a latitudinal shift north in the more recent part of the tracking period (Fig. 7b), due to a shift in resource availability; which is addressed in detail below.

Fig. 6 – Carnaby's cockatoo release in the Pinjar pine plantation in March 2018. Photo credit: Karen Riley.

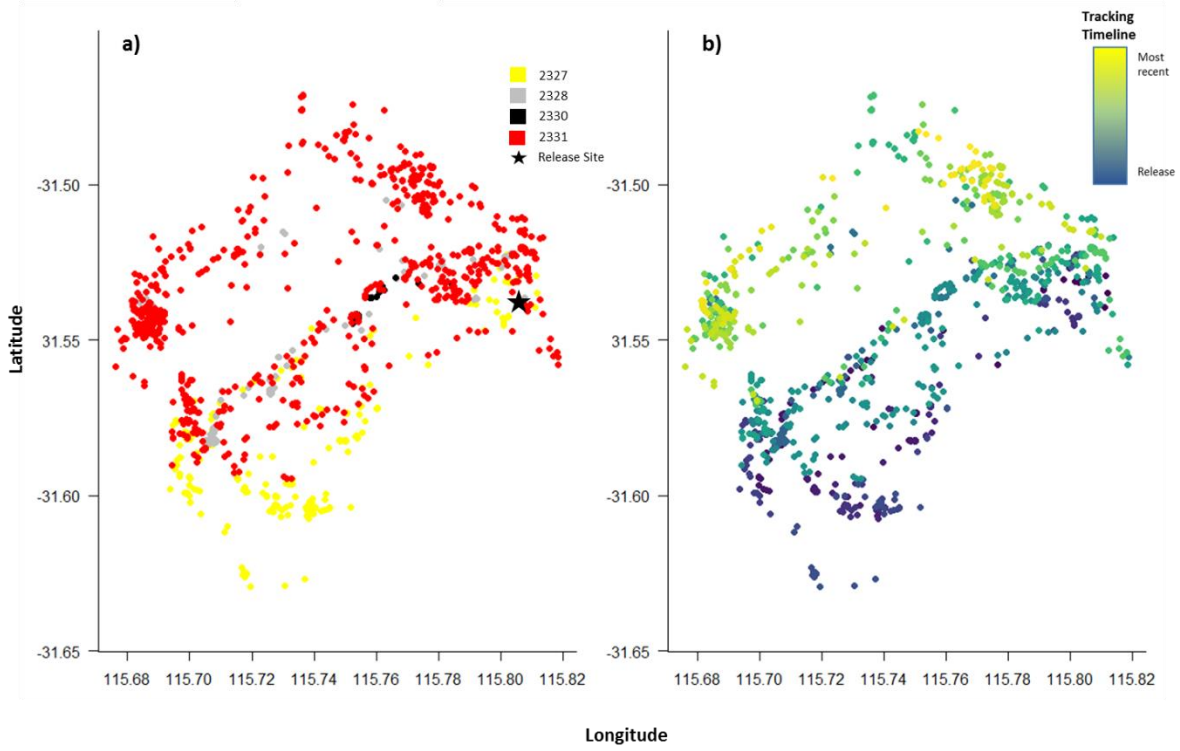


Fig. 7 – Distribution of tracks from four Carnaby's cockatoos released in the Pinjar pine plantation in March 2018. a) Apparent latitudinal separation suggests that the release birds joined two day-foraging flocks. CC12 (tag 2327) and CC14 (tag 2331) were confirmed to have joined flocks using BCPA; b) a distinct northern shift in the tracks is shown in the later part of the tracking period.

Revisitation statistics derived from the day and night data analysed separately revealed consolidated roost locations in the Pinjar pine plantations, a movement corridor to day foraging locations, as well as the identification of key foraging and watering sites during different times in the tracking period. The birds also showed clear activity periods of morning foraging, day roosting, afternoon foraging and night roosting. Longest residence times were during morning foraging and night roosting. Afternoon foraging activity, which was associated with shorter residence times, was indicative of birds foraging opportunistically as they moved back to the night roost (Fig. 8).

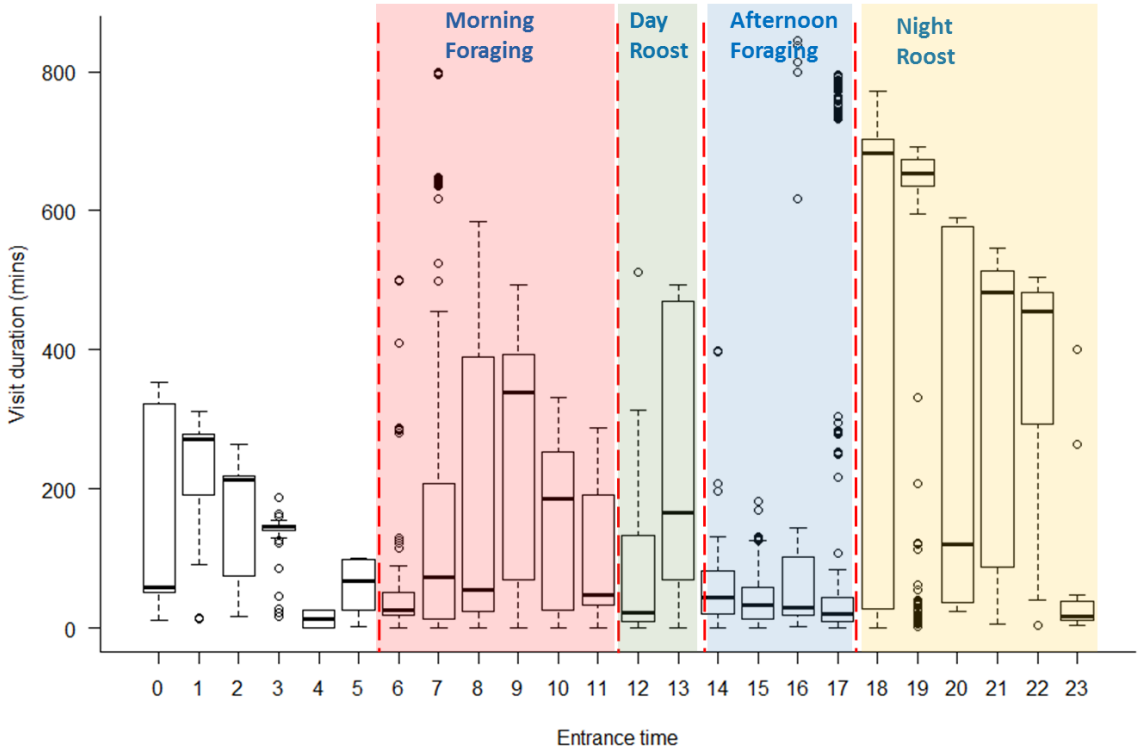


Fig. 8 – Temporal pattern of residence time based on hour of the day for Carnaby's cockatoos released at the Pinjar pine plantations (N=4). Longest residence times were associated with morning foraging and night roosting.

Night Roosts in the Pinjar Plantations

Pooling the data from the Gnangara release birds gave 18 potential roost nights, which during the period of GPS tracking were concentrated at three locations in the Pinjar pines (Fig. 9a). This was confirmed independently using cluster analysis (Fig. 9b). These sites were

consistent with known roosts from the Birdlife Western Australia Great Cocky Count data (GINYEAR003 and WANYANR001).

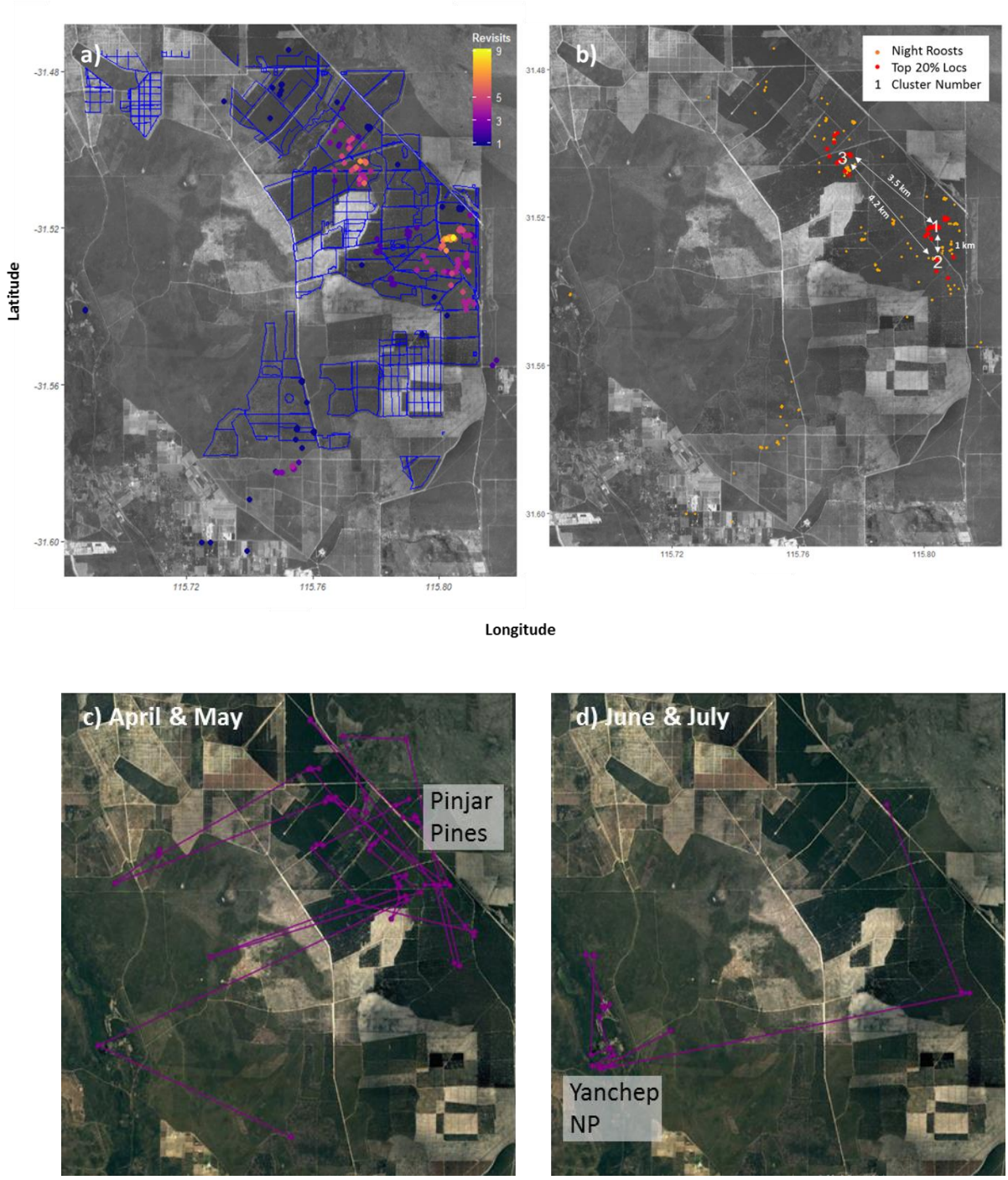


Fig. 9 – a) High use night roost locations for Carnaby's cockatoo based on 18 days of GPS data. Blue polygons are pine blocks in the Pinjar pine plantation; b) roost locations were confirmed using Cluster analysis and are consistent with long-term roosts that have been monitored by Birdlife Australia in the Great Cocky Count; Satellite tracking data collected from 20:00hr to 00:00hr and 06:00 to 10:00hrs shows a shift from c) roosting and morning foraging in the Pinjar pines in April and May to d) roosting and foraging in Yanchep National Park in June and July; which is consistent with a geographic shift in resource availability when the pine forage was depleted.

GPS data ceased in early March 2018. Long-term satellite data for CC14, however, show that this bird and its flock continued to roost and morning forage in the Pinjar pines in April and May (Fig. 9c). Once the pine resource was exhausted, the flock moved to Yanchep National Park, where it foraged and roosted in native vegetation and used Loch McNess as a water resource (Fig. 9d). Roost locations in Yanchep National Park were again consistent with known roosts from the Birdlife Western Australia Great Cocky Count data (WANYANR006 and WANYANR007), and were confirmed with flock follow observations.

Day movement and foraging patterns and movement corridors

Both 'recurse' analysis and visual observation confirmed that birds were feeding in the Pinjar pines in the morning before following a consistent movement path to the south-west (Fig. 10). Flock follow observations showed birds foraging in native vegetation (Fig. 10) as they moved along this vegetation corridor. In the earlier part of the tracking period (Fig. 7b), most flock movement was concentrated to the south of latitude -31.55 (Fig. 10). In the latter part of the tracking period, day foraging was concentrated in Yanchep National Park. Reducing the circle radius in 'recurse' to 100m clearly identified areas with concentrated daytime activity (Fig. 11). It also suggested that flocks appeared to be making use of the market garden areas around Carabooda (Lat -31.600, Long 115.723) to drink. Flock observations showed the birds drinking at irrigation points, or from the water captured by the crops, but not feeding on the crops. Once the crops were harvested and irrigation stopped, the birds moved their day foraging and drinking to Yanchep National Park. The smaller circle radius also revealed an important pine block to the west of the main Pinjar roost area that showed repeated use (Fig. 11).

Effect of pine resource depletion on day foraging and watering movement

By April and May of 2018 the pine food resource was starting to run out, and birds were observed feeding inside the pine blocks as well as on the ground in an effort to exhaust all the fallen cones (Fig. 12). By June and July, almost no activity was observed in the pines, and all effort had moved to foraging in native vegetation in the Yanchep National Park area. As there is no reliable/permanent water availability in the pines, the move away from this area is consistent with changing food resource availability.

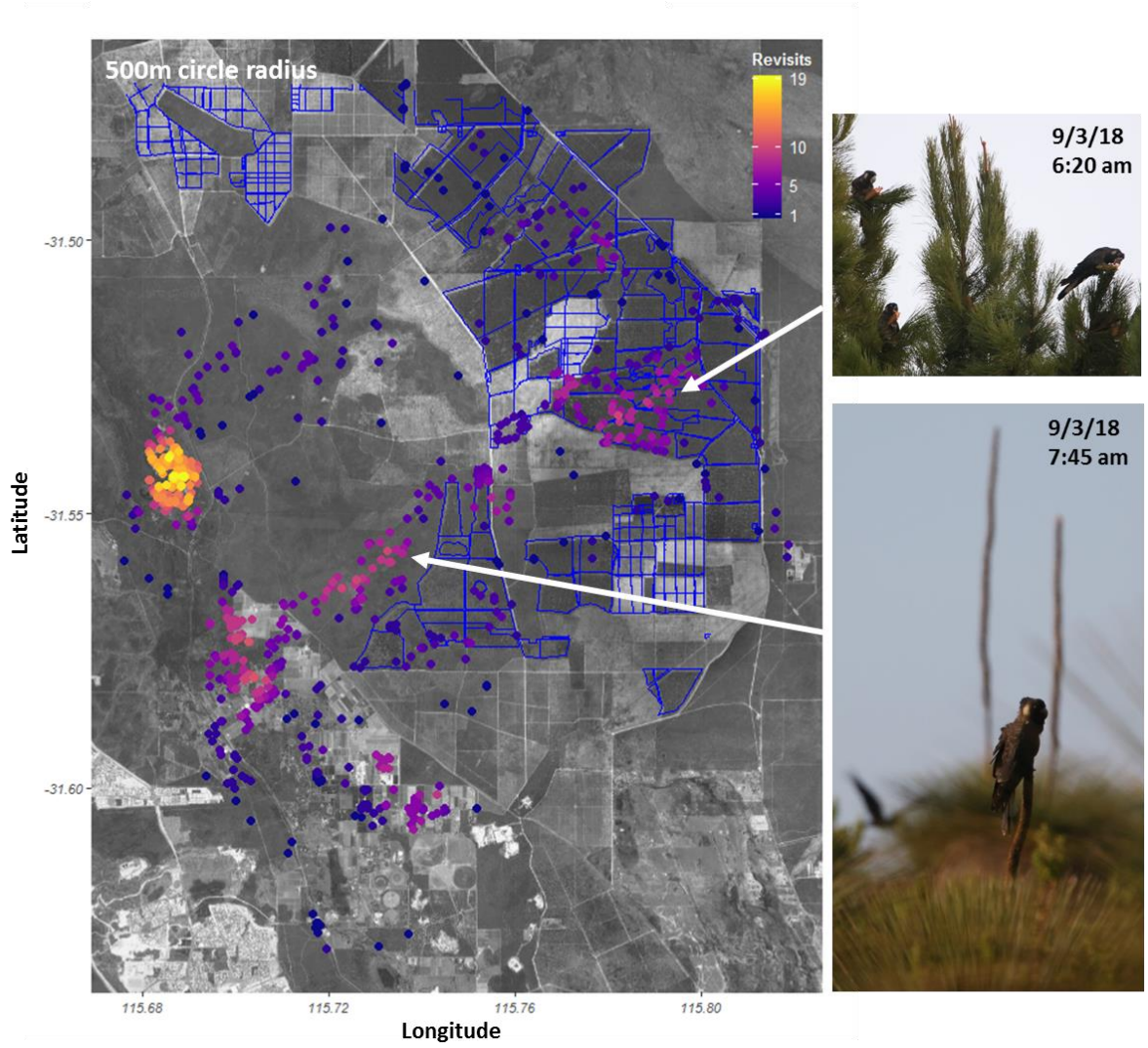


Fig. 10 – Day feeding and drinking activity by Carnaby's cockatoos roosting in the Pinjar Pine Plantations identified using revisitation statistics. A 500m circle radius was used to enable capture of movement corridors. A well-used corridor is shown to the south-west of the pine plantations that flocks used to fly to the market garden area in Carabooda, where they drank from irrigated crops. Feeding activity was validated using flock follow observations. Photo credit: Karen Riley.

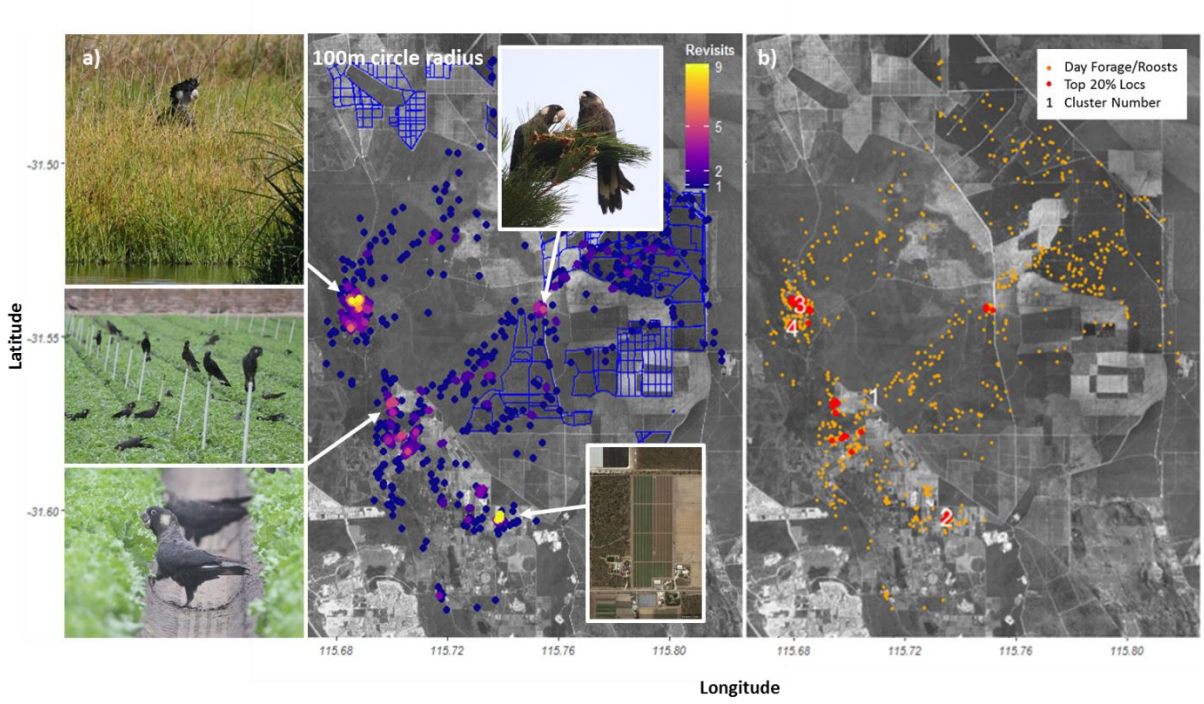
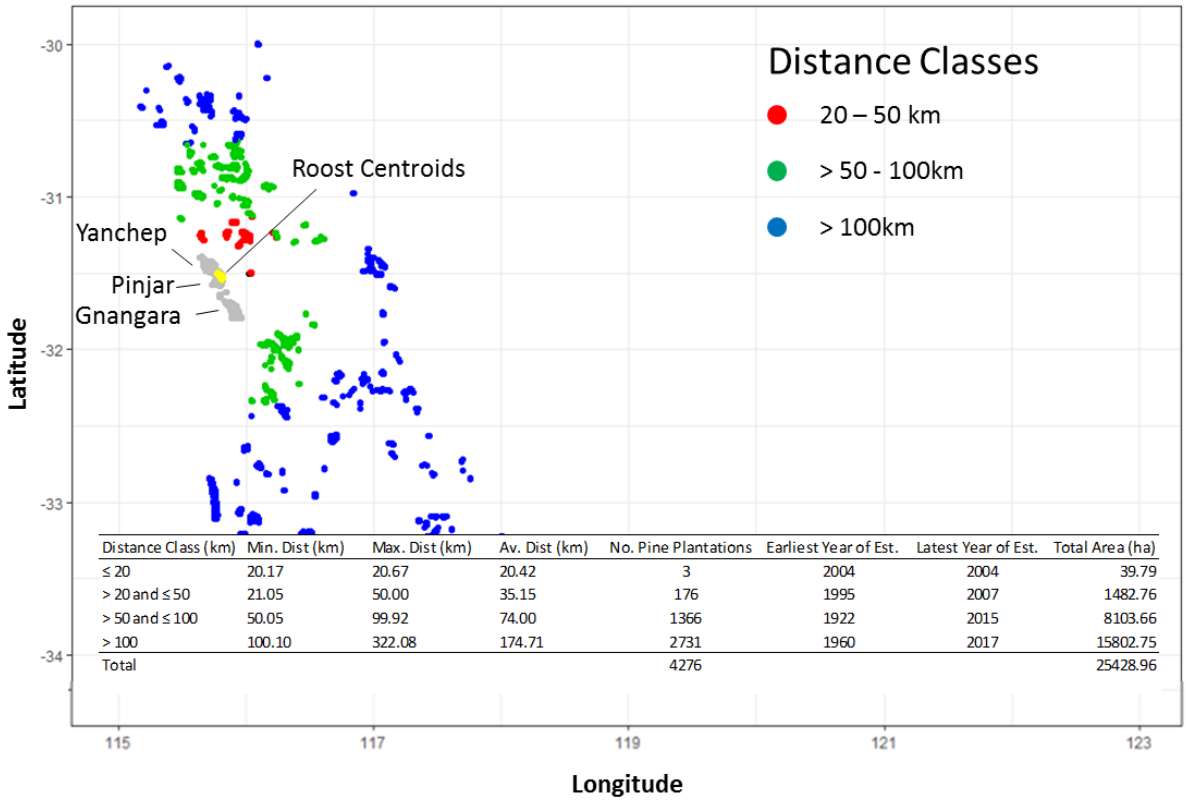


Fig. 11 – Revisitation statistics using a smaller circle radius of 100m clearly identifies areas of feeding and drinking concentration: a) once irrigation of the market gardens stopped following harvest, all day feeding and drinking behaviour moved to Yanchep National Park (Lat -31.548, Long 115.685); b) cluster analysis confirms the location of feeding and drinking. Photo credit: Karen Riley.

Fig. 12 – a) Carnaby's cockatoos feeding on fallen pine cones in the Pinjar Pine Plantations in April and May 2018; b) evidence of feeding deep inside plantation blocks and flying to the ground to find fallen cones (April and May 2018); c) by June and July 2018 large flocks of Carnaby's cockatoo were seen in Yanchep National Park where there is native forage and permanent water. Photo credit: Karen Riley.

Potential use of Midwest pine plantations by birds using the GYP pines

A total of 4,276 *P. pinaster* and *P. radiata* blocks across 485 plantations were between Latitudes -30.0 to -33.5 and Longitude <119.0. This number excludes any blocks within the GPY plantations (Fig. 13). Only three plantations with a total area of 39.79ha are within 20km of the principal roosts identified using the 'recurse' and cluster analysis (Fig. 9a and 9b).



Distance Class (km)	Min. Dist (km)	Max. Dist (km)	Av. Dist (km)	No. Pine Plantations	Earliest Year of Est.	Latest Year of Est.	Total Area (ha)
≤ 20	20.17	20.67	20.42	3	2004	2004	39.79
> 20 and ≤ 50	21.05	50.00	35.15	176	1995	2007	1482.76
> 50 and ≤ 100	50.05	99.92	74.00	1366	1922	2015	8103.66
> 100	100.10	322.08	174.71	2731	1960	2017	15802.75
Total				4276			25428.96

Fig. 13 – Distribution of pine plantation blocks within different distance classes from the three roosts in the Pinjar pine plantation. Only the block centroids are shown, and are colour coded according to distance class. Plantations within the GPY were excluded from the summary statistics in the table.

Many more are contained in the next distance class (N=176; >20 and ≤50km); nevertheless both distance classes are greater than the average 16km return trip that birds were found to make on the SCP (Table 1). Use of plantations in the 50^{+} km classes (green and blue in Fig. 13) by birds from the SCP would be part of a seasonal migration movement. It is possible based on our data that CC14 and its flock may have used Chittering Plantation as a roost or foraging site (if mature cones were still available) during the migration movement to Julimar National Park (Fig. 5d), but we did not capture tracks indicating this. Based on track data

from the birds in this study, the Midwest pine plantations are not an alternate food resource to Carnaby's cockatoos on the SCP during the non-breeding season.

The role of habitat corridors based on tracking on the SCP and in the Great Southern Wheatbelt

The tracking data used in this study show a clear relationship between occupancy and vegetation, irrespective of whether the vegetation was in remnant stands, metropolitan parks, fringing vegetation along roads or pine stands. Flight speeds are higher and transit times are faster where birds crossed cleared, or non-vegetated, areas. In most cases, birds avoided such areas (Fig. 14).

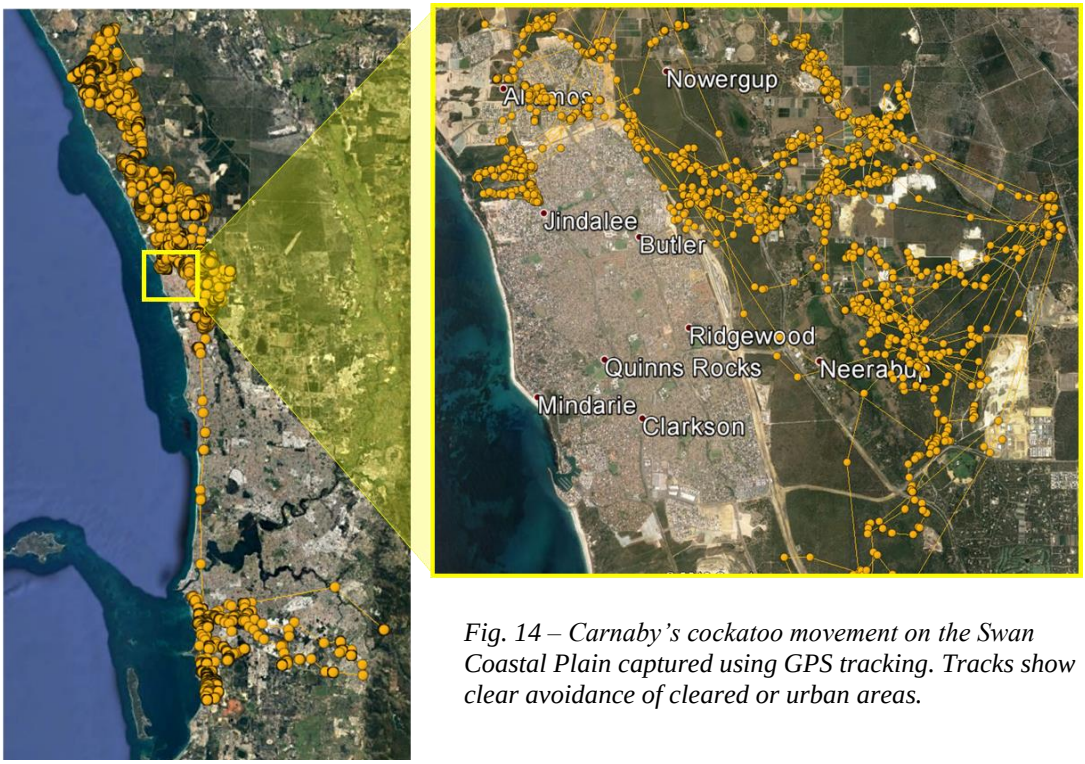


Fig. 14 – Carnaby's cockatoo movement on the Swan Coastal Plain captured using GPS tracking. Tracks show clear avoidance of cleared or urban areas.

Small remnant vegetation patches could provide potential corridors, as seen in Figure 15 where CC4 used a small remnant park with tall established trees for night roosting and an adjacent native remnant for foraging; though notably this bird and its flock were transiting this area rather than resident. Similar patterns of movement were captured by other tracked birds and their flocks.

Fig.15 – The value of small remnant patches of metropolitan parkland and native bush to assist with the movement of Carnaby's cockatoos through urban landscapes. Notably cleared areas, or areas containing relatively new housing, are avoided by CC4 and its flock. The blue symbol shows night roosting in Eastwell Park that contains large trees, and day foraging in Halesworth Park which contains native food trees. Photo credit: Karen Riley.

Movement in the Great Southern Wheatbelt also emphasises the importance of fringing vegetation along roads and the importance of retaining native vegetation blocks for foraging. In Figure 16, two birds tagged as part of a breeding ground study near Borden on the southwest of Western Australia show clear movement paths along roads, with day movement associated with transit to and from native habitat patches. Figure 17 also demonstrates a concentration of movement tracks along roads. Figures 14 to 17 all clearly show the effect of clearing on movement paths and the potential effect that retained vegetation corridors can have on retaining functional movement in this species.

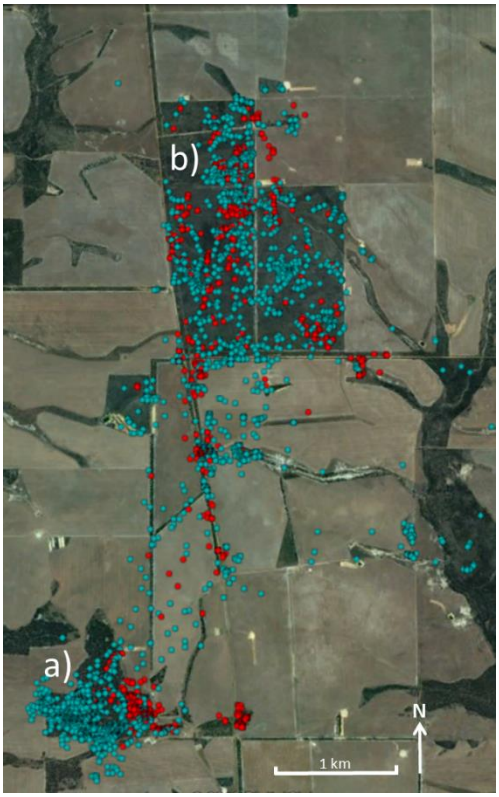


Fig. 16 – Daily foraging tracks from two Carnaby's cockatoo moving between: a) a breeding site near Borden, Western Australia; and, b) a foraging site in native vegetation. Other movement is also concentrated in areas with retained vegetation.

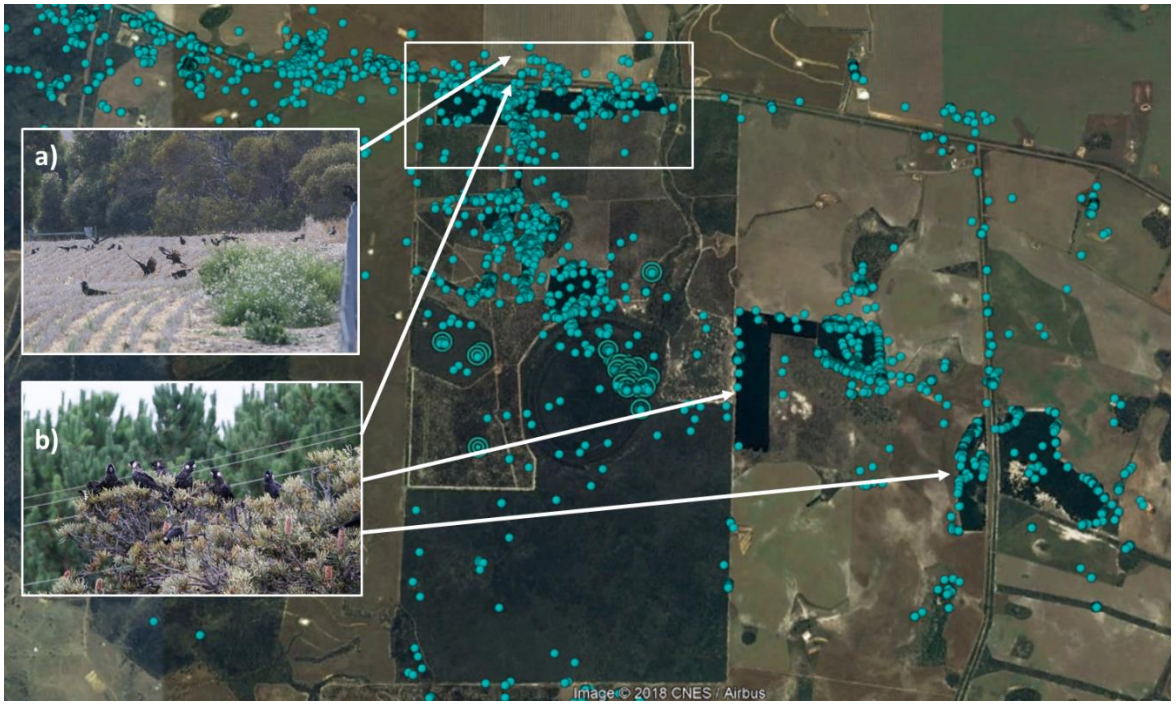


Fig. 17 – Foraging movement in Carnaby's cockatoo in the Great Southern Whealtbelt. Birds show a strong association with fringing road vegetation. In this example, birds are foraging on: a) recently harvested canola; and, b) adjacent pine blocks. Both resources are within 3km of night roosts indicated by the large circles.

Discussion

There is no evidence based on the data used in this study that tracked flocks made use of Midwest pine plantations north or east of the SCP. The only exception may be if CC14 and its flock used Chittering Plantation during the migration movement to Julimar National Park. This suggests that plantations other than the GPY are of value as a potential food source during migration movements to breeding grounds, or when at breeding grounds in the case of the flocked birds that moved to Myalup and Capel River, but are not used by birds on the SCP during the non-breeding period.

Carnaby's cockatoo flocks are mobile, but average daily return flight distances of less than 20km indicate that flocks restrict their movement during the non-breeding period, with daily flights limited to foraging and drinking. Flocks clearly modify their daily movement to respond adaptively to shifting food resources or water availability, and as a result, all tracked birds showed small-scale geographic variation in roost location (Fig. 4). The track data also showed other ranging movements related to night roost shifts, but these were relatively short distance geographic shifts preceding a new stable pattern of daily movement. In each case, distances were not consistent with flocks moving from the SCP to access Midwest pine plantations. Yet it is clear that some regional population(s) of Carnaby's cockatoo are making use of this resource, and new tracking studies are required to identify these populations, and to confirm if Midwest pines are a valuable food resource during the breeding season to either regional or GPY populations.

Based on the work of Rowe (2018), who divided the Midwest pine plantations into five regions, sampling 18 transects within each region to quantify cone damage as a function of Carnaby's cockatoo foraging effort, 92% of all sample plots contained some level of cone predation. The most heavily predated plantations were in the coastal Midwest and the Gingin Regans Ford region. No birds were observed during the Rowe (2018) survey period, and it is not clear whether time-since-predation was considered; however, the surveys took place in November to December, when breeding age birds are at breeding grounds, suggesting that predation was limited to non-breeding Midwest populations.

Several large roosts are centred in Gingin township. We have released tagged birds in 2016 and 2017 into this population; however, the data show movement limited to the greater Gingin area, or toward the coast. One bird did move to Julimar National Park during the

breeding period. During the time that these tags were working, there was no evidence of movement or interchange with the SCP, and as a result, these data are not discussed further.

Both the data and field observations showed that birds make use of natural and artificial water sources on the SCP. Movement of the birds to the market garden region in Carabooda appeared linked specifically to drinking from the crop irrigation. Once the irrigation stopped, the birds no longer visited. Field observation indicated that the birds did not appear to be eating the crops. Artificial provision of permanent water close to night roosts or high quality foraging sites may assist with retention of birds on the SCP.

Daily movement distances were too small to address the role of vegetation corridors and water adjacent to Midwest plantations, or to prioritise the importance of individual plantations as potential cockatoo resources (Aim 4 and 5). However, the value of vegetation to function as movement corridors is evident both on the SCP and from tracking data in the Great Southern Wheatbelt, and should be considered in future management.

Pine is of high value to Carnaby's cockatoos as it supports both roosting and feeding. In general, however, on the SCP and throughout the wheatbelt, vegetation types that support night roosting and day feeding are different. High quality native forage such as banksia woodland does not generally contain appropriate night roost trees. While not explicitly addressed in this report, there is a clear pattern in the data of pairing between roost and foraging locations. In combination with water, the retention of both habitat types is required within the landscape to support populations of Carnaby's cockatoo.

As both pine and native food resources are seasonal, the combined impact of continued clearing of native vegetation of the SCP and the projected food shortages forecast for 2019-2024, due to continued clearing of GPY plantations, raises the issue of whether there will be sufficient food on the plain to support the current population. This should be considered in parallel with the resource modelling completed by Williams et al. (2017). The current data indicate that the Midwest pine plantations are not a viable alternate food resource for non-breeding Carnaby's cockatoos on the SCP.

Future research recommendations

GPS and satellite tracking of birds is required in late September or early October to catch movement away from the PPCP to breeding areas. The timing of this is particularly important to target the manner in which flocked birds move through the peri-urban and Wheatbelt landscape to key breeding habitats in the Midwest. Focussing on releases as this time of year should inform the location of known and new breeding areas; and, given the retention times of the satellite tags, this also maximises our opportunity to capture return migration to the PPCP. The number of tags deployed needs to be sufficient to account for the percentage of birds that may move south to breeding grounds as well as east to the Wheatbelt region.

Additional tracking at key breeding sites is also needed to capture detailed GPS movement in the breeding areas to enable fine-scale visualisation and analysis of foraging patterns on the breeding grounds. This additional tracking work will also assist in identifying which populations are making use of the Midwest pine plantations.

References

Birdlife International. 2013. *Zanda latirostris*. The IUCN Red List of Threatened Species 2013: e.T22684733A48062560.

Bivand, R., and N. Lewin-Koh. 2018. maptools: Tools for Reading and Handling Spatial Objects. R package version 0.9-3. .

Bouten, W., E. W. Baaij, J. Shamoun-Baranes, and K. C. Camphuysen. 2013. A flexible GPS tracking system for studying bird behaviour at multiple scales. Journal of Ornithology **154**:571-580.

Bracis, C., K. L. Bildstein, and T. Mueller. 2018. Revisitation analysis uncovers spatio-temporal patterns in animal movement data. Ecography **41**:1801-1811.

Calenge, C. 2006. The package "adehabitat" for the R software: A tool for the analysis of space and habitat use by animals. Ecological Modelling **197**:516-519.

CLS. 2007-2014. Argos User's Manual: Wordwide tracking and environmental monitoring by satellite. CLS Publishing.

Cochran, W. 1980. Wildlife Telemetry. Pages 507-520 *in* S. Schemnitz, editor. Wildlife Management Techniques Manual. Wildlife Society, Washignton DC, USA.

Department of Environment and Conservation. 2012. Carnaby's Cockatoo (*Calyptorhynchus latirostris*) Recovery Plan. Perth, Western Australia.

Finn, H., G. W. Barrett, C. Groom, M. Blythman, and M. R. Williams. 2014. The 2014 Great Cocky Count: a community-based survey for Carnaby's Black-Cockatoos (*Calyptorhynchus latirostris*) and Forest Red-tailed Black-Cockatoos (*Calyptorhynchus banksii naso*). Perth, Western Australia.

Glossop, B., K. Clarke, D. Mitchell, and G. Barrett. 2011. Methods for mapping Carnaby's cockatoo habitat. Department of Environment and Conservation.

Government of Western Australia. 2015. Perth and Peel Green Growth Plan for 3.5 million. Strategic Assessment of the Perth and Peel Regions. Draft Action Plan E: Harvesting of pine and post-harvesting land use. Department of Premier and Cabinet, Government of Western Australia.

Gurarie, E. 2014. bcpa: Behavioral change point analysis of animal movement. R package version 1.1.

Gurarie, E., R. D. Andrews, and K. L. Laidre. 2009. A novel method for identifying behavioural changes in animal movement data. Ecology Letters **12**:395-408.

Johnstone, R., and T. Kirkby. 2008. Distribution, status, social organisation, movements and conservation of Baudin's Cockatoo (*Calyptorhynchus baudinii*) in South-west Western Australia. Records of the Western Australian Museum **25**:107-118.

Johnstone, R., T. Kirkby, and K. Sarti. 2013a. The breeding biology of the Forest Red-tailed Black Cockatoo *Calyptorhynchus banksii naso* (Gould) in south-western Australia. I. Characteristics of nest trees and nest hollows. Pacific Conservation Biology **19**:121-142.

Johnstone, R., T. Kirkby, and K. Sarti. 2013b. The breeding biology of the Forest Red-tailed Black Cockatoo *Calyptorhynchus banksii naso* (Gould) in south-western Australia. II. Breeding behaviour and diet. Pacific Conservation Biology **19**:143-155.

Kenward, R. 2001. A manual for wildlife radio tagging. Academic Press, UK.

Lee, J., H. Finn, and M. Calver. 2013. Ecology of black cockatoos at a mine-site in the eastern Jarrah-Marri forest, Western Australia. Pacific Conservation Biology **19**:76-90.

Maechler, M., P. Rousseeuw, A. Struyf, M. Hubert, and K. Hornik. 2018. cluster: Cluster Analysis Basics and Extensions. R package version 2.0.7-1.

Peck, A., G. Barrett, and M. Williams. 2017. The 2017 Great Cocky Count: a community-based survey for Carnaby's Black-Cockatoo (*Calyptorhynchus latirostris*), Baudin's

Black-Cockatoo (*Calyptorhynchus baudinii*) and Forest Red-tailed Black-Cockatoo (*Calyptorhynchus banksii naso*). Birdlife Australia, Floreat, Western Australia.

Peck, A., G. Barrett, and M. Williams. 2018. The 2018 Great Cocky Count: a community-based survey for Carnaby's Black-Cockatoo (*Calyptorhynchus latirostris*), Baudin's Black-Cockatoo (*Calyptorhynchus baudinii*) and Forest Red-tailed Black-Cockatoo (*Calyptorhynchus banksii naso*). Birdlife Australia, Floreat, Western Australia.

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Rowe, A. 2018. Factors influencing the foraging ecology of the endangered Carnaby Black Cockatoo (*Calytorhynchus latirostris*) within Maritime Pine (*P. pinaster* Ait.) plantations of the Avon wheatbelt bioregion. Forest Products Commission, Western Australia.

RStudio Team. 2016. RStudio: Integrated Development for R. RStudio, Inc., Boston, MA.

Rycken, S., K. S. Warren, L. Yeap, B. Jackson, K. Riley, M. Page, R. Dawson, K. Smith, P. R. Mawson, and J. M. Shephard. 2018. Assessing integration of black cockatoos using behavioral change point analysis. The Journal of Wildlife Management **83**:334-342.

Saunders, D. 1986. Breeding-Season, Nesting Success and Nestling Growth in Carnabys Cockatoo, Calyptorhynchus-Funereus-Latirostris, Over 16 Years at Coomallo Creek, and a Method for Assessing the Viability of Populations in Other Areas. Wildlife Research **13**:261-273.

Saunders, D. 1990. Problems of survival in an extensively cultivated landscape: the case of Carnaby's cockatoo *Calyptorhynchus funereus latirostris*. Biological Conservation **54**:277-290.

Saunders, D., I. Rowley, and G. T. Smith. 1985. The effects of clearing for agriculture on the distribution of cockatoos in the southwest of Western Australia. Pages 309-321 *in* A. Keast, H. Recher, H. Ford, and D. Saunders, editors. Birds of Eucalypt Forests and Woodlands: Ecology, Conservation, Management. Royal Australasian Ornithologists Union and Surrey Beatty & Sons.

Saunders, D. A., and J. A. Ingram. 1998. Twenty-eight years of monitoring a breeding population of Carnaby's Cockatoo. Pacific Conservation Biology **4**:261-270.

Shah, B. 2006. Conservation of Carnaby's Black-Cockatoo on the Swan Coastal Plain, Western Australia. Birds Australia, Perth, Western Australia.

Vavrek, M. J. 2011. fossil: palaeoecological and palaeogeographical analysis tools. Palaeontologia Electronica, 14:1T.

Western Australian Planning Commission. 2010. Directions 2031 and Beyond - Metropolitan Planning Beyond the Horizon. Department of Planning, Perth, Western Australia.

Williams, M. R., C. J. Yates, D. A. Saunders, R. Dawson, and G. W. Barrett. 2017. Combined demographic and resource models quantify the effects of potential land-use change on the endangered Carnaby's cockatoo (*Calyptorhynchus latirostris*). Biological Conservation **210**:8-15.

Yeap, L., J. M. Shephard, W. Bouten, B. Jackson, R. J. Vaughan-Higgins, and K. Warren. 2017. Development of a tag-attachment method to enable capture of fine- and landscape-scale movement in black-cockatoos. Australian Field Ornithology **34**:49-55.