Woolgoolga to Ballina Pacific Highway upgrade

Coastal Emu Monitoring Program Annual Report 2018

Construction Phase (Year 2)

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Pacific Highway Upgrade Woolgoolga to Ballina

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Contents

1. Introduction

1.1 Background and objectives

The Pacific Highway upgrade from Woolgoolga to Ballina (W2B) is currently under construction. The project was approved in 2014 under the NSW *Environmental Planning and Assessment Act,* 1979 and the Commonwealth *Environment Protection and Biodiversity Conservation Act*, 1999. The conditions of approval included preparation and implementation of a Coastal Emu Management Plan (Plan). This Plan outlines objectives and a methodology for undertaking a monitoring program to monitor the effectiveness of mitigation measures for Emus (*Dromaius novaehollandiae*). The program commenced prior to construction of the upgrade to gather baseline (pre-construction) data and is to continue through the construction and early operational stages of the highway. The results of the monitoring are required to inform an adaptive mitigation strategy and thereby assist with the ongoing management of any identified impacts to Emus as a result of the project.

The monitoring program aims to determine if the mitigation measures for Emus have been effective in the long-term and therefore achieve the mitigation goals in the plan. The underlying objectives of the program are to:

- Further understand and monitor distribution, abundance and habitat use by Emus near the road corridor.
- Identify temporal trends in the relative abundance of Emus in impact and control areas during the different stages of the project to identify if the project is having a negative impact on Emu presence.
- Evaluate the success of mitigation measures largely designed to allow Emu's safe passage across the highway corridor (i.e. temporary and permanent crossing structures, exclusion and hybrid fences and habitat revegetation for Emus).

Pre-construction monitoring was conducted between December 2013 and December 2016 and the results reported in three annual reports (Jacobs 2014; 2015; 2016). Construction of the W2B upgrade for Section 4 commenced in mid-2016 and in Section 3 in January 2017 (Year 1). The construction phase of the Emu monitoring program commenced concurrently. This report outlines the methods and results of continued Emu monitoring during the second year of construction up to December 2018 and compares all construction survey data with the pre-construction baseline and previous construction periods.

1.2 Overview of the monitoring program

The Management Plan outlines an adaptive and responsive management approach, whereby information on the occupancy of Emus within and adjacent to the project area will be used to inform mitigation measures and ongoing monitoring. The program is based on a BACI approach (Before, After, Control, Impact), monitoring Emu distribution and relative abundance at a set of impact and control site comparing the 3-year baseline dataset with monitoring data collected seasonally during construction and operational monitoring will continue for five years after which will be subject to performance review with possible extension to at least 7 years (RMS 2015, Section 7.2.1).

Results from the monitoring program during construction and operation would be analysed after each sampling period and annually. Regular analysis of the data is conducted to allow improvements and refinements in the survey design to be incorporated into future monitoring activities. Indicative triggers for the monitoring program are reported in the management plan and are to be reviewed and assessed with consideration of baseline data. These triggers relate to a notable decline in Emu activity in the project area compared to control sites, the extent of normal decline in activity will be determined using the baseline data.

Impact sites are in the vicinity of Section 3 of the W2B upgrade. Sites have been selected to survey both forest and floodplain grazed habitats within proximity to the project corridor, and particularly east and west of proposed Emu crossing zones. Control sites were selected in coastal forest and grassland habitats which resemble the impact sites and are expected to have regular Emu presence. Additional observational data is collected and stored as a register of Emu sightings near the project corridor maintained during construction for both Section 3 and 4 of the W2B upgrade. These data are also discussed in the annual report and used to inform management decisions.

Aspects of the pre-construction study included an experimental trial to test the effectiveness of temporary fencing for future use as road exclusion mitigation and as a means of directing Emus to future crossing zones and a provision of early Emu crossing areas to educate Emus to cross the future highway at dedicated locations that align with the final bridge designs. It is intended to continue monitoring a subset of the Emu crossing zones during construction where purpose-built Emu races have been provided and this would be expanded to monitoring a larger set of Emu crossing structures during operation.

The management plan identifies mitigation goals for each phase of the project from pre-construction, through construction and operation. The degree to which these goals are achieved, or fail is referred to as 'performance' and is measured through monitoring and implementing corrective actions where performance criteria are not met. The specific mitigation goals relevant to the coastal Emu monitoring program are:

- Zero rate of traffic related Emu mortality in Sections 3 and 4 of the Pacific Highway after 10 years.
- Post-mitigation occupation in the study area is similar to pre-road construction occupation after 5 years.
- Post-mitigation presence on both sides of the road is similar to pre-road construction presence.
- Zero or reduced rate of Emu deaths from dog attacks in vicinity of crossing structures in Section 3 and 4 of Pacific Highway in years 1-5.

The monitoring program aims to determine if the mitigation measures for Emus have been effective in the long-term and therefore achieve these mitigation goals.

2. Monitoring methods

2.1 Site occupation surveys

2.1.1 Study areas

Monitoring Emu occupancy was conducted at impact and control sites that focused on five study areas:

1. Pillar Valley west (PV), including land east and west of the Tucabia-Tyndale Road and portions of the Coldstream wetland, and lower catchment of Pillar Valley Creek and Black Snake Creek (project Section 3).
2. Tucabia south (MR) between Mitchell Road and Firth Heinz Road (project Section 3)
3. Tucabia north (TN) from Bostock Road to Sommervale Road and west to Pine Brush State Forest, including Champions Creek (project Section 3)
4. Yuraygir south (YS) at two locations around Diggers Camp and Minnie Waters (Control)
5. Yuraygir north (YN) at two locations around Brooms Head and Taloumbi (Control).

The intent of the sampling regime is to compare Emu presence over time within each of these study areas relative to the different project phases rather than a comparison between areas. This was achieved by sampling between 2 and 5 transects in each study area using transects that range between 800 and 2000 metres in length. In total 24.7 km of transects were sampled from 13 impact sites and 7 control sites (Table 1). Sites were stratified to sample a range of different habitat types including pastoral land, forest, riparian and wetland areas. The location of survey transects is shown in Figures 1-5.

Table 1 : Study areas, survey sites and details of Emu monitoring transects

Study area	Survey site	Status	Habitat	Transect length (m)	Search area (ha) based on 10 m transect width	Position relative to future road
Pillar Valley West (PV)	PV-A	Impact	Grazing / forest	840	0.84	West
	PV-B	Impact	Grazing / wetland	1300	1.30	West
	PV-C	Impact	Grazing / forest	1655	1.65	East
	PV-D	Impact	Grazing / forest	2425	2.42	East
			Total	6220 m	6.2 ha	
Tucabia South (MR)	MR-A	Impact	Open forest	825	0.82	East
	MR-B	Impact	Open forest	965	0.96	West
	MR-C	Impact	open forest	755	0.75	West
	MR-D	Impact	Swamp forest	700	0.70	West
	MR-E	Impact	Open forest	1400	1.40	East
			Total	4645 m	4.6 ha	
Tucabia North (TN)	TN-A	Impact	Open forest	2080	2.08	West
	TN-B	Impact	Grazing / wetland	645	0.64	West
	TN-C	Impact	Open forest	1365	1.36	East
	TN-D	Impact	Open forest	1200	1.20	East
			Total	5290 m	5.28 ha	
Yuraygir South (YS)	YS-A	Control	Forest / heath	1155	1.15	-
	YS-B	Control	Forest / heath	1255	1.25	-
	YS-C	Control	Open forest	1030	1.03	-
	YS-D	Control	Open forest	730	0.73	-
	YS-E	Control	Open forest	1250	1.25	-
			Total	5420 m	5.4 ha	
Yuraygir North (YN)	YN-A	Control	Forest / heath	1850	1.85	-
	YN-B	Control	Open forest	1270	1.27	-
			Total	3120 m	3.1 ha	

FIGURE 1 | Yuraygir South

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FIGURE 2 | Pilar Valley West

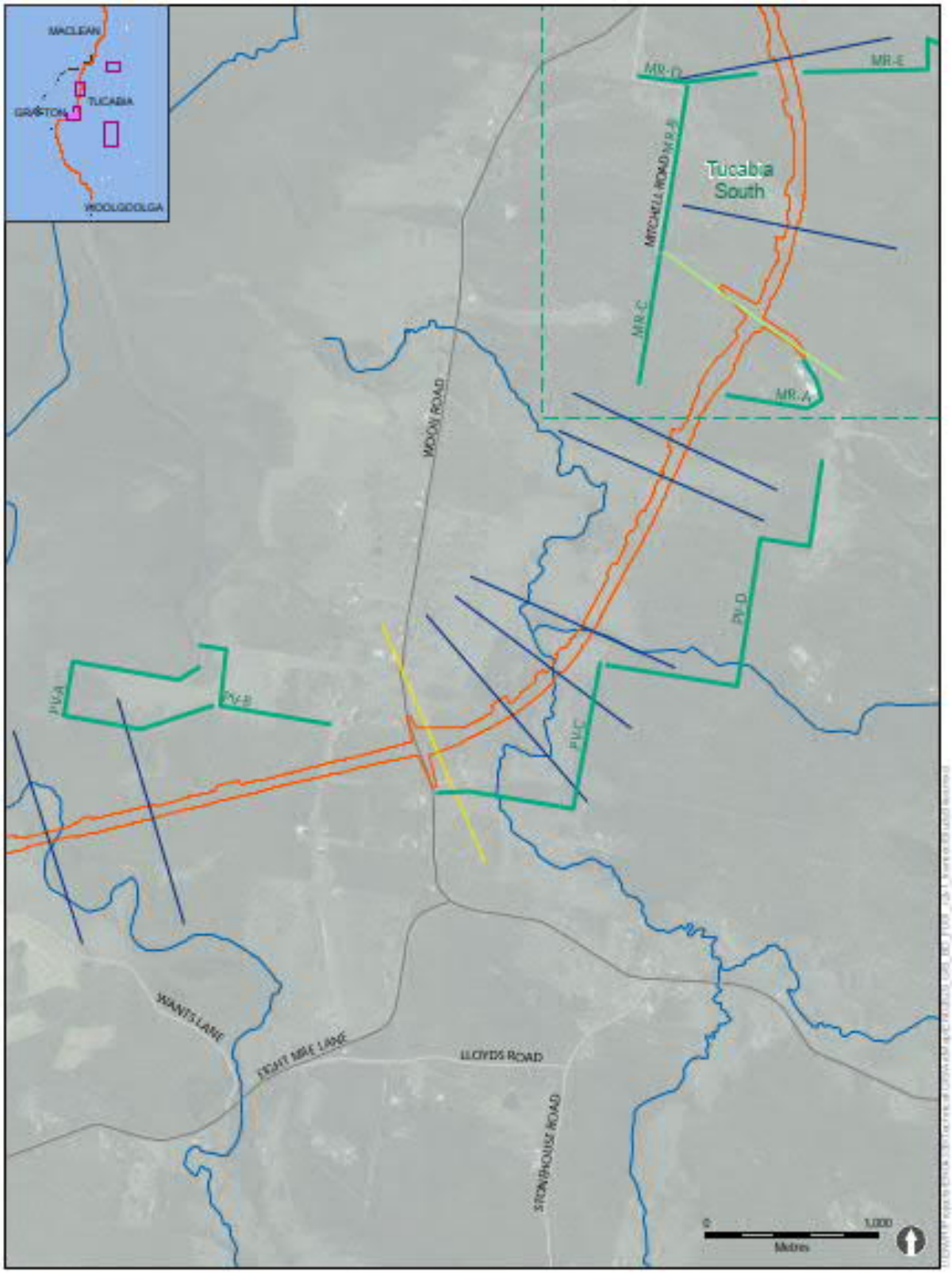

FIGURE 3 | Tucabia South

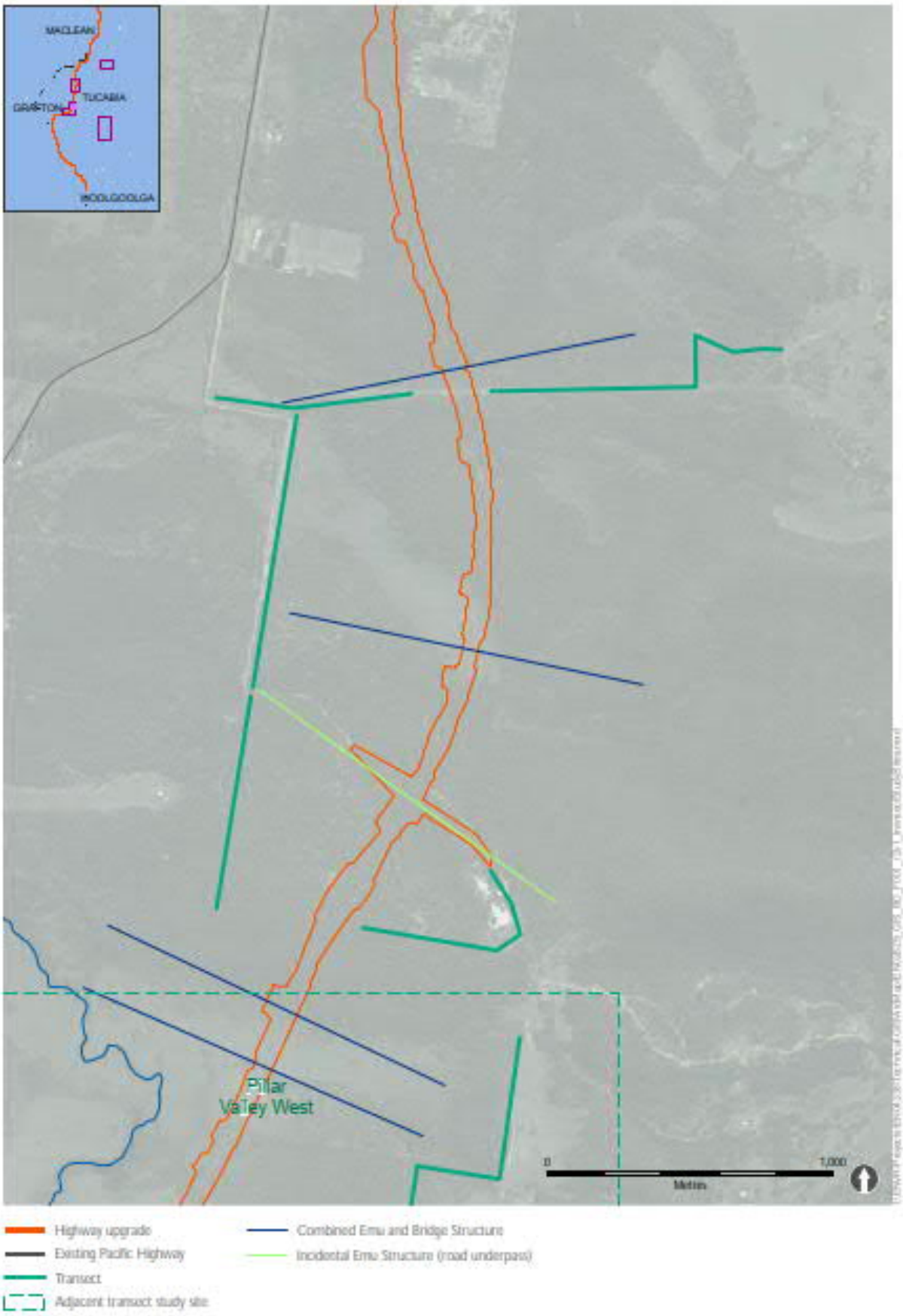

FIGURE 4 | Tucabia North

FIGURE 5 | Yuraygir North

2.1.2 Timing

Monitoring of spatial and temporal presence of Emus relied on two methods centred on each transect, 1) searches for Emu signs and 2) camera trapping. Sign searches and the download of photographs is conducted at four quarterly events targeting the end of each season (i.e. February, May, August and November). In this way evidence of Emu presence and captured photographs was collated for each season.

2.1.3 Sign searches

Each of the 20 transects is walked once over a week-long (5 days) survey during each season and sampling period. Transects are searched throughout daylight hours (0730 to 1700) and involve a single observer walking slowly along the designated transect route and actively searching for signs of Emu presence (i.e. droppings, feathers, and footprints) concentrated over a 10 m wide search area centred over the transect (refer plates 1-4 for examples of Emu sign). Transects were purposefully positioned along fence lines where possible, as barbed wire has been found to be an effective means of snagging feathers from Emus passing through the fence (refer Jacobs 2014) and hence a reliable method of observing signs to monitor presence at a site.

The number of signs detected is counted and then removed from each transect. For footprints this means raking over sand and mud and for feathers and droppings removing from the transect. This is done in order to capture fresh signs over the following season and sampling period. In addition to recording signs, any actual observations of Emus in the vicinity of transects during the survey week are recorded and contact with landowners where possible during the course of the survey week to document any observations of Emus made by the property owner since the last monitoring event.

Plate 1. Example of Emu feathers ‘snagged’ on barbed wire

Plate 2. Emu dropping with Gahnia sieberiana seed

Plate 3. Example of muddy transect where Emu tracks are apparent

Plate 4. Example of sandy transect where Emu tracks are apparent

2.1.4 Camera trapping

The use of motion sensor cameras provides a second technique for confirming presence and also captures information on actual date present on the transect, confirms whether multiple birds were present and breeding success through recording images of juveniles with adult males. Camera trapping used fixed cameras, triggered by motion sensors, to 'trap' images of passing Emus. Up to two camera traps were maintained semi-systematically along each of the transects, to provide a total of between 4-9 cameras per study area. Cameras are occasionally moved to new locations along transects during subsequent surveys if found to be unsuccessful from the preceding survey period or stolen or in response to finding Emu signs.

Details on camera trapping effort during each project phase are summarised in Table 2. The summary data shows a comparison of the trap effort in the first two years of construction with the 3-year pre-construction baseline dataset. In general, the mean number of trapping days per camera and total camera trap effort recorded during construction was comparable across each study area with the pre-construction surveys.

Traps were placed on trees at a height of approximately 1.5 metres above ground and were not baited. Cameras were set to take pictures 12 hours per day in daylight hours, with a 5 second delay between exposures to minimise repeat photographs of the same animal while allowing continuous recording to capture additional Emus in the case of multiple birds or juveniles.

The date and time of each exposure are recorded and used to determine if multiple pictures were taken of the same animal to discard consecutive observations. Cameras were left in the field continuously and batteries and storage cards replaced at each survey week as discussed previously in timing. Broken, malfunctioning and stolen cameras are replaced as required.

Cameras are also used to detect the presence and trap rates of wild dogs within each study area. This information is used to understand any correlation between the presence/absence of Emus and detect if any changes in dog activity around crossing zones.

Table 2: Summary and comparison of camera trapping effort during the course of the monitoring program

Sampling period	Survey effort	Impact areas			Control areas	
		Pillar Valley west	Tucabia south	Tucabia north	Yuraygir north	Yuraygir south
Pre-construction (data shown is the means recorded over 13 quarterly monitoring sessions)	Camera monitoring days per season	90.3	90.3	90.3	90.3	90.3
	No. successful cameras	6.1	8.8	5.1	3.2	6.3
	Mean trapping days per camera	71.9	70.5	71.8	69.2	64.7
	Total camera trap effort (days)	438.5	637.8	380.6	232.6	429.5
Year 1 of construction (data shown is the mean recorded over 4 quarterly (seasonal) monitoring sessions)	Camera monitoring days per season	89.5	89.5	89.5	89.5	89.5
	No. successful cameras	6.0	8.8	6.5	4.0	6.8
	Mean trapping days per camera	65.7	71.8	84.1	75.1	61.7
	Total camera trap effort (days)	405.5	685.5	538.0	316.5	412.3
Year 2 of construction (data shown is the mean recorded over 4 quarterly (seasonal) monitoring sessions)	Camera monitoring days per season	91.0	91.0	91.0	91.0	91.0
	No. successful cameras	6.7	8.7	7.7	3.7	6.5
	Mean trapping days per camera	73.93	74.20	80.45	86.18	70.80
	Total camera trap effort (days)	495.3	645.5	619.5	318.9	460.2

2.1.5 Data analysis and limitations

We correlated trapping rates of Emus with densities estimated from counts of signs made along the search transects. Two indexes of relative abundance were calculated using:

- Number of signs for each transect divided by the search area (transect length x 10 m) reported as density of Emu signs per hectare.
- Camera trapping rate, defined as the ratio of Emu photographs to the number of trap days multiplied by 100. This provided a comparable index of density as individual recognition of photographed Emus and hence capture-recapture analysis was unfeasible. Where multiple pictures were taken of the same animal at the same time these were discarded from the trapping rate calculations. Multiple Emu photos in the same frame were counted as separate Emu photos.

From the combined sign and camera trapping data we created an Emu detection history at each transect consisting of binary values with '1' indicating Emu detected during the sampling period and '0' indicating non-detection. We analysed the detection history to identify the proportion of impact and control sites occupied in each study area during each sampling event (i.e. site occupation rates).

Data on density of Emu signs, and trap rates of Emus during the construction phase were compared with pre-construction baseline data at impact and control sites to identify any significant changes using Analysis of Variance (ANOVA). Occupations rates were compared using a t-test analysis.

Where possible transects have been placed along fence lines, and 3 and 4 strand barbed wire fences are particularly effective at identifying Emu presence. Not all transects were able to be located on suitable fence lines, which is limited where plain wire is present or there is no fence. However, this factor does not affect the long-term comparison of results, as the conditions have not changed from the baseline survey. Occasionally fences have been replaced or sections removed and resulting in a change to the effectiveness of the transect at detecting Emu presence. To overcome this limitation, small changes or additions have been made to the transect, while still maintaining a similar search length and area of the transect.

2.2 Emu crossing zones

A set of eight Emu crossing zones were established across the construction corridor in Section 3 and are maintained during construction in compliance with the Emu Management Plan. These are referred to in the Plan as 'Emu races'. An Emu race consists of a temporary fenced passageway running perpendicular and below the

width of the construction corridor for the purpose of providing Emus an opportunity to cross the road corridor during construction. The objective of the races is to maintain Emu connectivity across the alignment in key locations during construction. Specifically, Section 5.3.4 of the Emu Management Plan states:

Given a potential lengthy construction period for Section 3 of the project, the Stage 2 construction phase must make available a number of options for Emus to cross the corridor during construction. The objective is to maintain functional crossing zones during construction where possible.

Emu races are reportedly closed during construction hours using temporary fencing (gates) positioned along the road boundary, to restrict Emus from moving onto the construction corridor while work is being conducted and therefore at risk of collision. These gates are then routinely removed outside of construction hours (i.e. each evening through to early morning and every Sunday), effectively opening up the Emu race. The position of the eight Emu races are aligned with temporary fence gaps trialled for 12 months prior to construction to provide some certainty that these locations are suitable (refer Table 3 for details).

Table 3. Details of Emu races maintained during construction

Emu Crossing Zone	Station (Chainage)	Description / waterway / habitat	Emu race details
T1	46.055	Bridge A10 Pillar Valley Creek Bridge 1 - Floodway adjacent to Pillar Valley Creek / riparian habitat	Established 1st Quarter 2017. Typical width 10 metres (range 2.5 m to 15 m). 4 cameras set 21.2.2017 and maintained continuously through year 1 and 2.
T2	46.325	Bridge A11 Pillar Valley Creek Bridge 2 - Pillar Valley Creek / riparian habitat	Established 2nd Quarter 2017, typical width 12 metres (range 8 m to 16 m). 4 cameras set 23.05.2017 and maintained continuously through year 1 and 2.
T3	46.647	Bridge A12 Pillar Valley Creek Bridge 3 - Black Snake Creek / riparian habitat	No, race has been substituted with the race at 47.000. Closed during construction
T4	47.000	North of Black Snake Creek / cleared grazing land habitat	Established 1st Quarter 2017, new race established to compensate for loss of T3 (T4A). Typical with 4 m (range 4 m to 7 m). 2 cameras set 21.02.2017 and maintained continuously. This temporary crossing and race was closed during 2018 and no further monitoring to occur.
	47.125	A54 Twin Bridge for Emu Crossing 1 - Floodway / cleared grazing land habitat	Established 3rd Quarter 2017, typical width 3.5 m (range 1.5 m to 5 m) (T4B). 2 cameras set 21.8.2017 and maintained continuously through year 1 and year 2.
T5	47.643	Bridge A13 Pillar Valley Creek Bridge 4 - Floodway / cleared grazing land habitat	Established 4th Quarter, typical width 4 metres (range 2.5 m to 4 m), 2 cameras set 21.08.2017 and maintained continuously through year 1 and 2.
T6	47.925	Bridge A14 Pillar Valley Creek Bridge 5. Un-named creek / swamp forest habitat.	Established 1st Quarter 2017, typical width 12 metres, 4 cameras set 21.2.2017 and maintained continuously through year 1 and year 2.
T9	49.246	Bridge A16 North of Pillar Valley Creek Bridge 1 - Floodway / cleared grazing land	Established 4th Quarter, typical width 2.5 metres (range 1.5 m to 8 m), 2 cameras set 21.08.2017 and maintained continuously through year 1 and 2.
T10	50.280	Bridge A17 North of Pillar Valley Cree Bridge 1 - un-named creek / swamp forest habitat	Established 1st Quarter 2017, typical width 3 metres (range 3 m to 4 m) 2cameras set 21.2.2017 and maintained continuously through year 1 and 2.

Monitoring of Emu usage across each race commenced as installation of the temporary structure was completed. This involved the placement of camera traps at the eastern and western entrance of the race, consisting of between 2-4 cameras depending on the width of the race. The number and configuration of cameras at each race aimed to confirm Emu usage and determine the frequency of Emu passes through the race. The cameras were set for continuous operation in daylight hours between 0500 and 2000 hours and set to take still images with a trigger interval of 5 seconds in attempt to capture direction of travel and groups of Emus.

During the camera checks at each quarterly survey period, the length of race was also walked to search for fresh signs of Emu activity (scats, tracks and feathers) to determine if Emus used the race but were not photographed in the event of a camera failure.

2.3 Emu sightings register

A register of Emu sightings in proximity to the project is maintained during construction by on-site personnel. The register has been maintained since the commencement of early works in Section 4 in mid-2016 and throughout the first two years of construction (2017-18). The register is a database for documenting sightings and observations of Emus within or adjacent to the construction corridor and has three objectives:

1. Manages potential impacts to Emus that may result from a collision with construction vehicles.
2. Informs environmental managers where additional mitigation or corrective actions may be required.
3. Provides supplementary Emu presence data to inform the monitoring program.

Section 5.3.2 of the Management Plan states:

Workers on site to actively note and report Emu sightings daily by recording number and location of Emus on map to be provided. Important to identify time and date, and number of birds including which side of the construction corridor Emus sighted.

The register was maintained as a manually recorded excel database for the majority of 2017, towards the end of the year a mobile spatial application was released by Pacific Complete (Arc Collector) as a more efficient means of collecting Emu observational data. This app will be maintained through the remainder of the construction phase.

3. Results

3.1 Sign searches

Each of the impact and control study areas have been occupied by Emus in at least one season during the first two years of construction, with exception of the Yuraygir south study area, which was no longer occupied over the last 18 months of the pre-construction period and throughout the construction monitoring periods. Signs of Emu presence were confirmed both east and west of the highway corridor during this period of construction, confirming that Emus have occupied habitat on either side of the road corridor during the construction phase.

The density of Emu sign during the two years of construction were lower from all three 'impact' study areas compared with the 3-year pre-construction period from the same locations (Figure 6). This was most notable from the Pillar Valley west transects. A similar pattern of decline in Emu sign during the construction phase was also noted in the 'control' areas, with a complete absence of Emu sign recorded in the Yuraygir south control sites and a marked decline c.50% from Yuraygir North during construction (Figure 7).

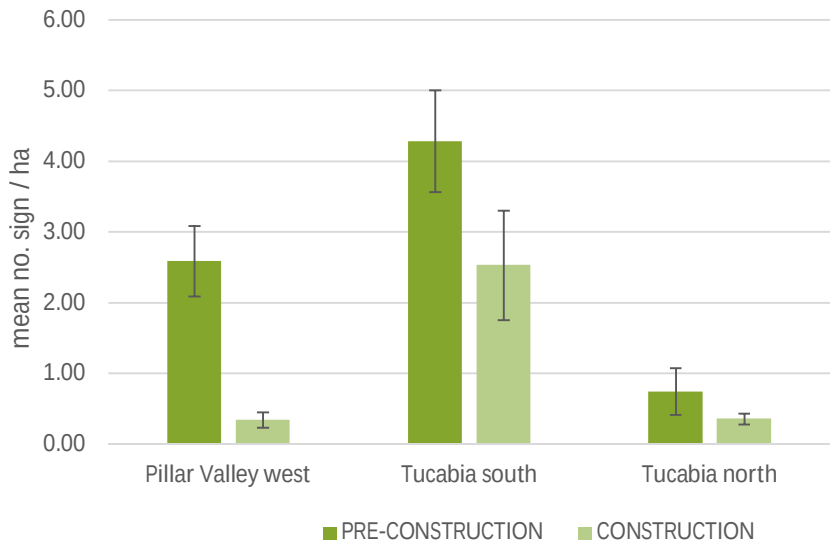

Figure 6: Mean density of Emu sign (no./ ha) at impact sites comparing pre-construction (2014-16) and construction (2017-18)

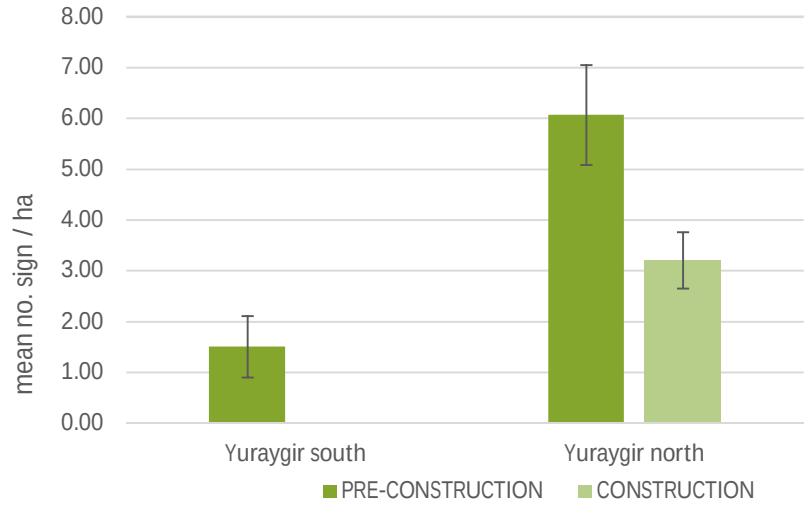

Figure 1 : Mean density of Emu sign (no./ ha) at control sites comparing pre-construction (2014-16) and construction (2017-18)

The decline in sign data during construction has been interpreted with consideration of the temporal patterns of Emu sign observed since 2014 which includes pre-construction and construction years. The density of Emu signs within each study area has varied over season and years. For example, pre-construction sign density was highest in 2014 before declining in 2015 and 2016, prior to construction commencing in 2017 (refer Table 4). Monitoring during construction occurred in 2017 and 2018 and the general trend of declining Emu sign has continued particularly in Pillar Valley west, although there was an increase from the baseline data to the north and south Tucabia in the first year of construction and then declining back to below baseline in 2018.

A one-way ANOVA (analysis of variance) was performed on the annual sign density values comparing each of the five years and then comparing the pre-construction years (before) with the construction years (after). These data indicate a significant decline in Emu activity in the Pillar Valley West area which was first noted prior to construction ($P = 0.004$). There was also a significant decline between 2015-16 (pre-construction) and 2017-18 (construction) ($P = 0.003$). These data suggest that the decline in Emu activity at the Pillar Valley west study area had started prior to construction and was consistent over the last five years. It is unknown whether this decline is due to actual lower Emu numbers or whether the individuals occupying these areas shifted away to other nearby areas. Indeed, the fact that remaining impact areas north and south of Tucabia showed a gradual decline during pre-construction and then an increase in Emu activity in the first year of construction may suggest the movement of birds from Pillar Valley west.

Table 4. Density of Emu sign per ha recorded at the three impact study areas during pre-construction (2014-16 blue) and during construction (2017-18 yellow)

Sampling period	Pillar Valley west					Tucabia south					Tucabia north				
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
Summer	2.56	2.56	0.64	0.32	0.48	6.52	7.61	3.26	6.52	1.09	0.00	0.95	0.19	0.57	0.19
Autumn	3.68	0.8	1.44	0.96	0.48	9.78	5.87	1.52	4.78	0.43	0.00	0.19	0.19	0.57	0.38
Winter	3.52	2.24	1.28	0.32	0	5.87	3.26	2.17	3.48	1.74	3.22	0.00	0.00	0.19	0
Spring	6.40	1.92	-	0.16	0	1.74	3.48	-	1.30	0.87	1.52	0.19	-	0.57	0.38
Summer	5.60	0.96	-	-		1.96	2.61	-	-	-	3.22	0.00	-	-	-
Mean	4.35	1.70	1.12	0.44	0.24	5.17	4.57	2.32	4.02	1.03	1.59	0.27	0.13	0.48	0.24
SE	0.71	0.35	0.19	0.16	0.14	1.51	0.94	0.39	0.98	0.27	0.72	0.18	0.05	0.08	0.09

The density of Emu signs has also declined in the Yuraygir (north and south) control study areas since 2014, particularly Yuraygir south where abundant sign was recorded between January 2014 and February 2015, compared with a complete absence of Emu sign across four sites since autumn 2015 (Table 5). These areas comprised breeding birds in 2014 and this absence is consistent with the NPWS annual citizen survey which did not record Emus from Minnie Waters or Wooli in 2015-2017 despite regular abundance in the year prior to 2015. The data suggests either a decline in Emu numbers at the control or a shift away from this study area to other proximal areas. This is direct evidence that Emu presence in a particular area can change in response to changing environmental variables or behavioural traits.

There have been no notable changes in density of Emu sign from the Yuraygir north control area ($P = 0.15$) over time.

Table 5. Density of Emu sign per ha recorded at the two control study areas during pre-construction (2014-16 blue) and the first and second year of construction (2017-18 yellow)

Sampling period	Yuraygir south					Yuraygir north				
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
Summer	5.53	0.18	0.00	0.00	0.00	1.28	7.37	2.88	5.77	1.28
Autumn	4.42	0.00	0.00	0.00	0.00	5.13	4.81	5.13	4.49	1.60
Winter	3.87	0.00	0.00	0.00	0.00	4.81	3.85	6.73	2.88	3.53
Spring	4.61	0.00	-	0.00	0.00	11.54	5.77	-	4.17	1.92
Summer	0.92	0.00	-	-	-	14.74	4.81	-	-	-
Mean	3.87	0.04	0.00	0.00	0.00	7.50	5.32	4.91	4.33	3.21
SE	0.78	0.04	0.00	0.00	0.00	2.45	0.59	1.12	0.59	0.56

3.2 Camera trapping

During the construction phase of the program Emus were photographed at 6 of the 20 transects surveyed (33 %) in the first year (2017) and 4 transects (20 %) in the second year (2018). This is compared with 61.1 %, 40 % and 30 % recorded during the 3-year pre-construction monitoring period. These data are consistent with the trends reported from the Emu sign analysis. Two of the impact study areas and one control study area recorded Emu photographs during at least one season. The exceptions were Pillar Valley west (impact) and Yuraygir south (control). Emus were photographed both east and west of the highway corridor during the first two years of construction confirming birds have occupied habitat either side of the road corridor in Section 3 during the construction period.

Mean camera trap rates in impact and control areas are shown in Figure 8, these show an overall comparison of the pre-construction data (2014-2016) with the first two years of construction (2017-18). There has been a trending decline in Emu trap rates from pre-construction through construction at both impact and control areas (72 % and 25 % respectively). There were no Emu photos captured at Pillar Valley west or Yuraygir south during construction and this is consistent with the low density of Emu sign reported in these areas. An Emu was photographed in Tucabia north for the first time during construction in 2017 and again at the same site 6 months later. Photographs were captured of single birds only within the impact areas while an adult male with three juveniles was photographed at the Yuraygir north control study area in 2017. No photographs of juveniles were captured in 2018, however land owner sightings at the Yuraygir north control study area report evidence of breeding.

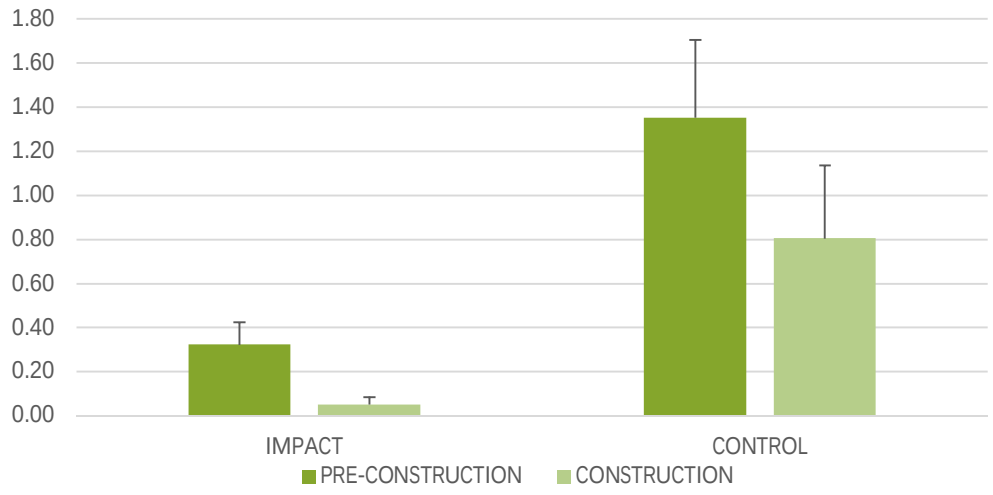

Figure 8: Mean camera trap rates (no. Emus photographed per 100 trap days) at impact and control study areas for pre-construction period (2014-16) and construction period (2017-18)

The camera trapping data is consistent with the declines noted in the sign density discussed previously. These data are presented in Tables 6 and 7 and show a decline in trap rates in the impact areas of between 36 – 80 % during the pre-construction years.

A one-way ANOVA (test of variance) was performed on the annual camera trap rates comparing each of the five years and then comparing the pre-construction years (before) with the construction years (after). These data indicate no significant differences in mean camera trap rates between years, with the exception of the Yuraygir south control study area where no Emus have been photographed after 2014.

Table 6. Camera trap rate (no. Emu photos / 100 trap days) per study area recorded at the three impact study areas during pre-construction (2014-16) and the first and second year of construction (2017-18)

Sampling period	Pillar Valley west					Tucabia south					Tucabia north				
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
Summer	0.00	0.00	0.19	0.00	0.00	2.99	1.51	0.51	0.17	0.00	0.00	0.00	0.00	0.00	0.00
Autumn	0.92	0.00	0.00	0.00	0.00	0.96	0.12	0.41	0.54	0.18	0.00	0.00	0.00	0.00	0.00
Winter	1.16	0.00	0.17	0.00	0.00	0.24	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.17	0.00
Spring	0.13	0.99		0.00	0.00	0.54	0.43		0.15	0.00	0.00	0.00		0.00	0.00
Summer		0.00					0.14					0.00			
Mean	0.55	0.20	0.12	0.00	0.00	1.18	0.44	0.37	0.21	0.05	0.00	0.00	0.00	0.04	0.00
SE	0.29	0.20	0.06	0.00	0.00	0.62	0.28	0.09	0.11	0.05	0.00	0.00	0.00	0.04	0.00

Table 7. Camera trap rate (no. Emu photos / 100 trap days) per study area recorded at the two control study areas during pre-construction (2014-16) and the first and second year of construction (2017-18)

Sampling period	Yuraygir south					Yuraygir north				
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
Summer	1.85	0.00	0.00	0.00	0.00	1.75	1.10	0.36	1.23	1.78
Autumn	2.23	0.00	0.00	0.00	0.00	0.97	2.06	0.00	1.92	1.28
Winter	1.54	0.00	0.00	0.00	0.00	6.38	0.00	4.35	2.92	1.79
Spring	1.01	0.00		0.00	0.00	4.67	2.74		0.99	0.95
Summer		0.00					1.42			
Mean	1.66	0.00	0.00	0.00	0.00	3.44	1.46	1.57	1.77	1.45
SE	0.26	0.00	0.00	0.00	0.00	1.26	0.46	1.39	0.22	0.1

Trap rates of wild dogs were also recorded to monitor change in dog presence in Emu study areas. Dogs were found to be present at all sites both during the pre-construction phase and construction phase, suggesting dogs and Emus co-exist within impact and control areas. There was a large decrease in dog presence recorded at impact sites during the early phase of construction which was also experienced at control areas.

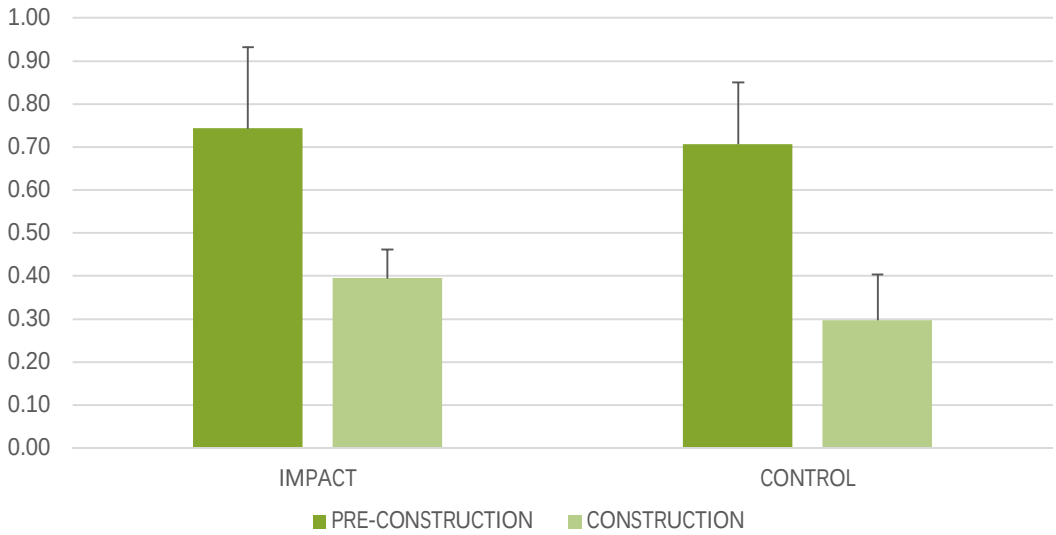

Figure 9: Mean camera trap rates (no. dogs photographed per 100 trap days) at impact and control study areas for pre-construction period (2014-16) and construction period (2017-18)

3.3 Site occupation

Data from the sign survey and camera trapping for each period of monitoring were combined to identify site occupation (i.e. the proportion of sites occupied by Emus within each study area over time). As the home range and distance travelled by coastal Emus is not well known, the data analysis has relied on the assumption that separate groups occupy the impact and control study areas. For example, it is feasible for the three impact study areas that the same Emus could be detected on any of the transects sampled. Therefore, for the purpose of comparing site occupation rates, the impact site data was assessed as one whole study area and the two control areas were assessed as a separate study area. This is because the control areas are spatially separated from the impact areas and therefore there is a low likelihood that the same Emus from the impact area would be detected in either of the control areas.

The number of sites occupied in any one survey period varied across season with more notable fluctuations in impact areas versus control areas. These variations are likely to reflect more pronounced movements of Emus around the project area (Pillar Valley and Tucabia) compared with Yuraygir north where sites are occupied year round (Table 9).

Table 9. Site occupation rates recorded seasonally at the impact and control study areas during pre-construction (2014-16 blue) and construction (2017-18 yellow)

Sampling period	Impact					Control				
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
Summer	85.6	84.6	30.8	61.5	46.2	91.6	42.9	28.6	28.6	28.6
Autumn	90.0	46.2	46.2	53.8	38.5	100.0	28.6	28.6	28.6	28.6
Winter	90.9	38.5	46.2	61.5	7.7	100.0	28.6	28.6	28.6	28.6
Spring	92.3	69.2	46.2	46.2	23.1	85.7	28.6	28.6	28.6	14.3
Mean	89.7	59.6	42.3	55.8	28.8	94.3	32.2	28.6	28.6	25.0
SE	1.45	10.6	3.85	3.68	6.03	3.39	3.58	0.0	0.0	2.52

Figure 10 compares the mean site occupation rate for the 13 pre-construction surveys (baseline) at impact and control sites and the mean rate from the 8 construction phase surveys. These two means were compared using an independent t-test with the dependent variable being occupation rate and the independent variable being time (pre-construction and construction). For the impact sites there has been a decrease in around 23 %

occupation of survey sites, a change that is statistically significant (*P = 0.023*). The decline is observable across the two construction years, with occupancy means recorded as low as 7.7 % in winter 2018. There has also been a statistically significant decline in the number of control sites occupied (*P = 0.01*). This decline was first noted in late 2015 during the pre-construction phase, associated with the absence of Emu activity in the Yuraygir south control sites. The mean decline is a factor of the higher occupation rates in the first year of the program commencing in 2014 through the latter two pre-construction years (2015 and 2016).

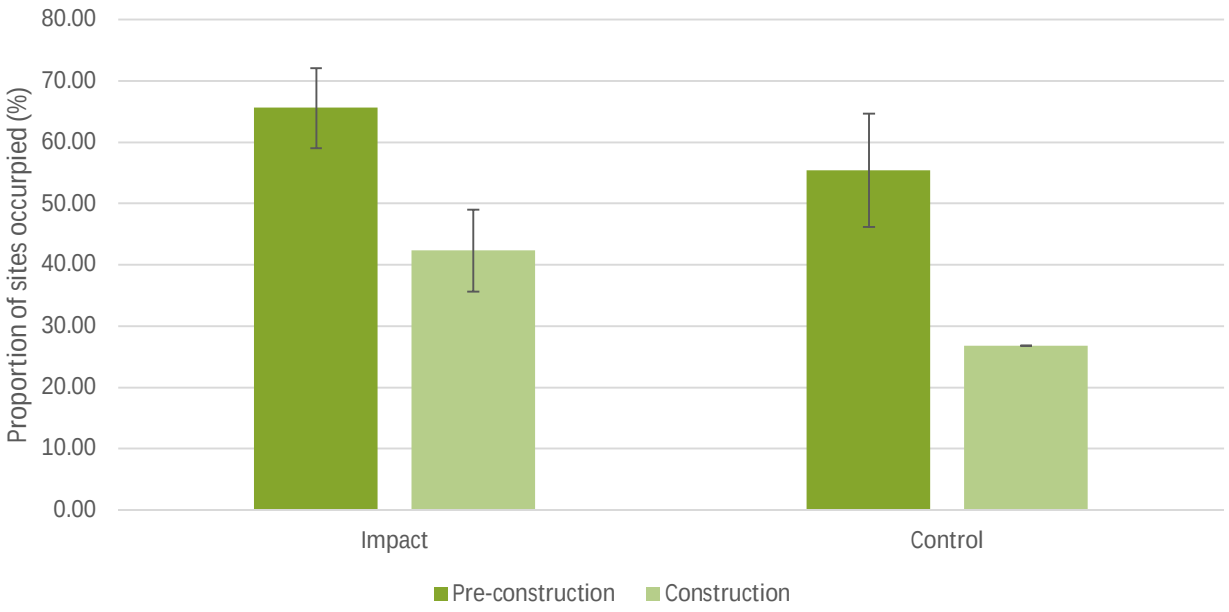

Figure 10. Mean occupation rates (±se) for impact and control sites comparing pre-construction (2014-16) with construction (2017-18)

3.4 Monitoring Emu crossing zones

Camera monitoring equipment was initially installed in the Emu races in February 2017, with further cameras added during the first year of construction as a race was completed. Up to 18 cameras functioned within 8 races during each of the seven construction monitoring periods. This resulted in a total of 6,449 camera trapping days and 187,552 photos. The majority of the photos taken were of construction vehicles and workers in addition to cattle and kangaroos using the races. An Emu was reported using one race in 2017 from a camera trap, and no further use was recorded in 2018. No Emus signs have been observed. In general monitoring of the races has been compromised by the high degree of construction activity in 2018, including the presence of vehicles and workers and also cattle and this is reflected by the very large number of photos taken of non-target items. As a result, it is possible that Emus have used a race in 2018 and this has not been detected.

The recorded low usage of the crossing zones could also be attributed to the fact that the crossing zones are closed six out of seven week days (open Sunday only) and are open mainly at night when Emus are not active. Further there has been inconsistent opening and closing of the race gates during this time. This can also be linked to the trending decline in Emu activity in Pillar Valley west across the 5-year monitoring period. Monitoring will continue through the third year of construction (2019). As construction activity declines in 2019 this may improve the effectiveness of the camera monitoring.

Plate 5. Emu crossing zone (race T9) May 2018

Plate 6. Emu crossing zone (race T5) May 2018

3.5 Emu sightings register

A total of 226 separate Emu sightings were recorded by construction workers between January 2016 and December 2018, this encompasses the early works activities in Section 4 which commenced in 2016 through to clearing and construction activities commencing in 2017 and monitoring through to the end of 2018 (year 2 of construction). These records account for 506 individual Emus sighted (although it should be noted that multiple records of the same birds are made on the same or consecutive days by different recorders). There were 27 observations of juveniles with an adult male, and this ranged from between 1 and 6 juveniles and 6 observations of more than one adult bird together. The majority of observations (89.5 %) were recorded in Section 4 of the project in the area between the Tyndale and Maclean interchanges, while 11 % were made south of Tyndale to Pillar Valley (8 Mile Lane) in Section 3. In 2018 all observations were reported in Section 4.

Emus were recorded in all months of the year, with peaks in May (autumn) and September-October (spring) around the cane properties north of Tyndale. In Section 3 more birds were recorded in summer and winter (Figure 12 and Figure 13) than Section 4. Soybean is grown in rotation with the sugarcane crop cycle and is typically sown in summer (Dec-Jan) with crops maturing and developing bean pods in April-May and are harvested early winter. Juveniles may be present with adult birds from June through to November. It appears that birds are less likely to be around cropping areas in summer, and more often sighted in grazing land and natural habitats.

Emus were sighted both east and west of the project corridor sometimes as close as 20 metres from the boundary and birds were observed either on the construction corridor or attempting to cross the corridor on 11 occasions in 2017-18, with 6 of these occasions during the early works phase (June-August 2016) when construction traffic was largely absent, or minimal. Two observations were in October 2016 and January 2017, preceding the vegetation clearing stage and increase in construction traffic and 3 observations were made in September 2019. All Emus observed near construction areas were managed in accordance with the Emu Management Plan, and there were no reported Emu incidents or mortalities associated with construction from 2016 to the end of 2018.

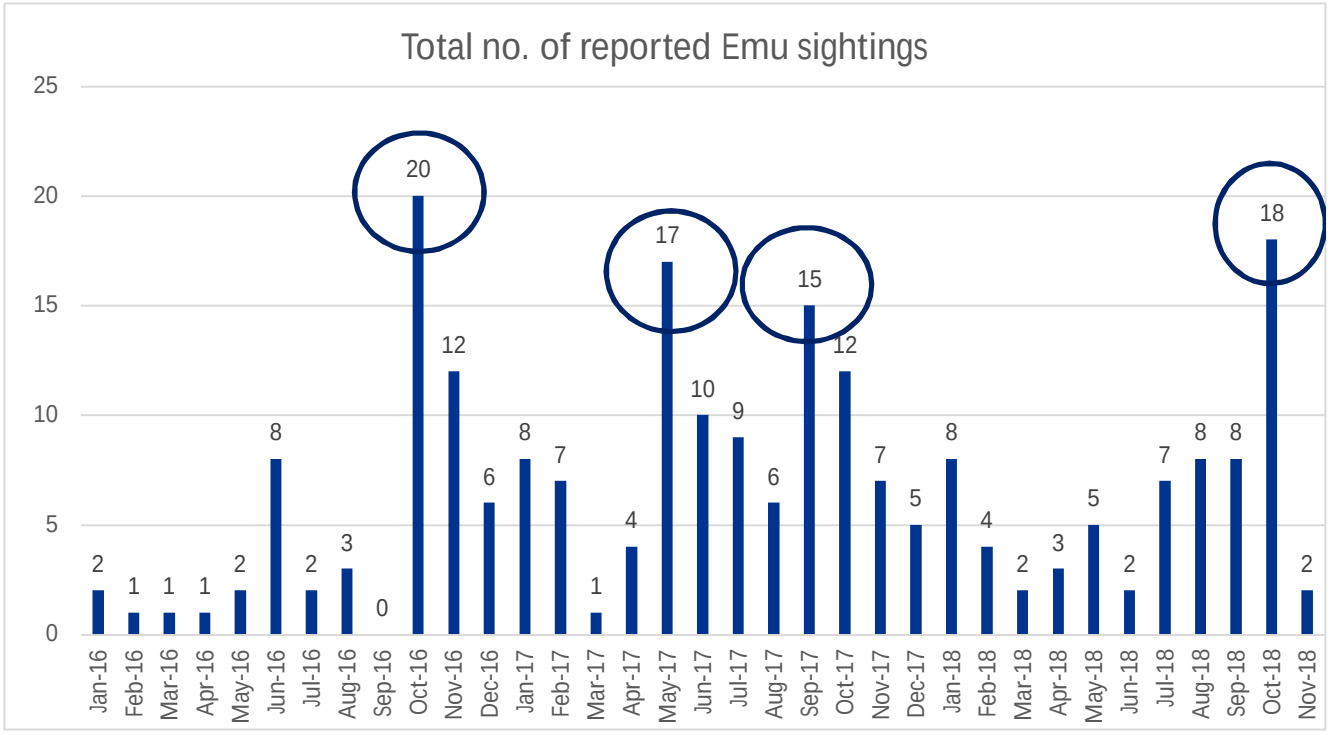

Figure 11. Total number of reported Emu sightings since start of construction of W2B upgrade (May 2016 – December 2018)

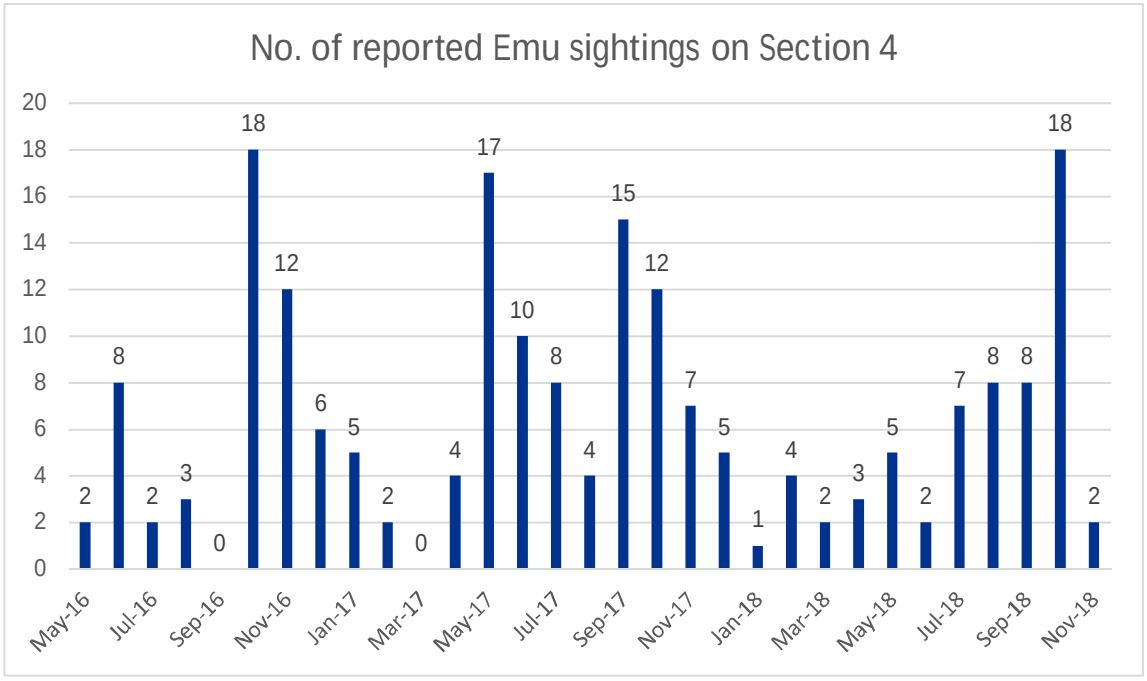

Figure 12. Number of reported Emu sightings in Section 4 of the W2B upgrade during construction (May 2016 – December 2018)

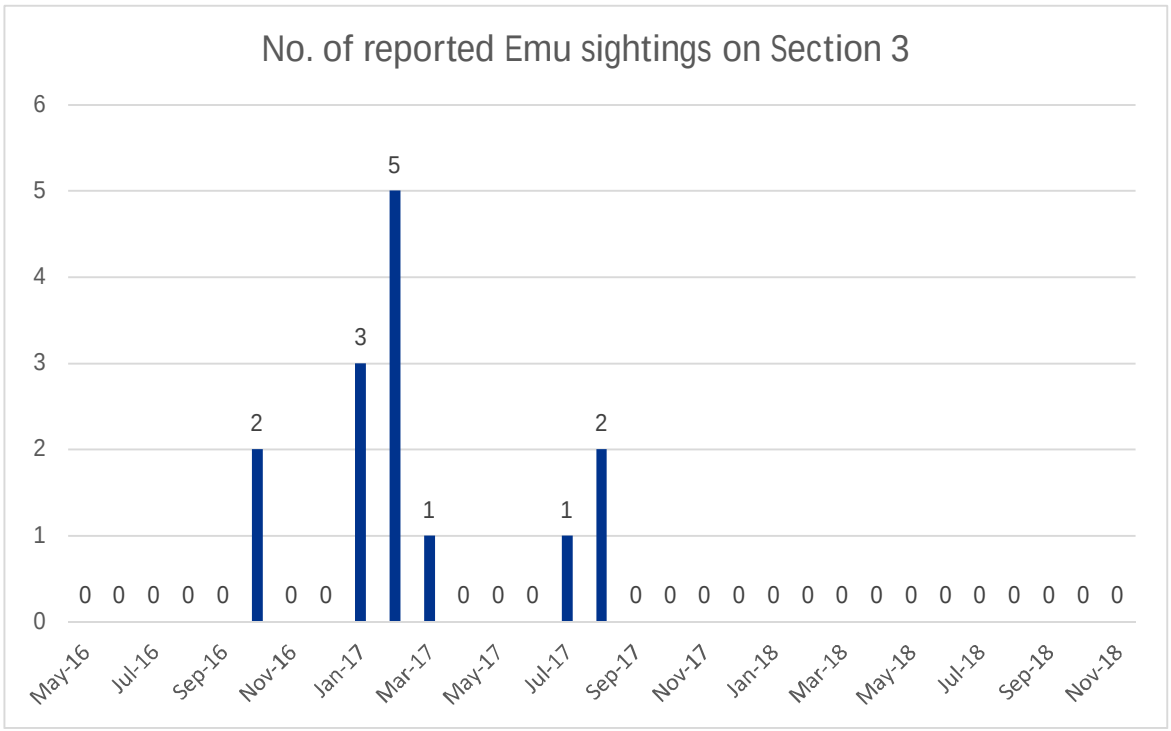

Figure 13. Number of reported Emu sightings in Section 3 of the W2B upgrade during construction (May 2016 – December 2018)

4. Discussion

4.1 Distribution and abundance

This report describes the methods and results of Emu activity monitoring conducted during the first two years of the W2B construction phase in Section 3 and 4. Monitoring has shown a decline in Emu activity that is consistent in Section 3 and the southern control area, in contrast to continued Emu activity in Section 4 and the northern control area. When comparing the occupation of Emus between the pre-construction and construction phases there has been 21 % decline in impact areas compared with 34 % decline in control areas.

The decline during construction has been interpreted with consideration of the temporal patterns of Emu sign observed since 2014 which includes pre-construction and construction years. The density of Emu signs and trapping rates has varied over season and years and the relative abundance of Emus was highest in 2014 before declining in 2015 and 2016 (prior to construction). Monitoring during construction commenced in 2017 at which point the general trend of declining Emu abundance in Section 3 has continued. The Yuraygir south control area comprised an abundance of Emu activity data and indeed breeding birds in 2014 before a complete absence of activity in late 2015 which has not returned. The data suggests either a decline in Emu numbers at both Section 3 and the control or individuals have shifted away from these locations to other proximal areas outside the survey area. This is direct evidence that Emu presence in an area can change in response to changing environmental variables or behavioural traits.

The contrast in the northern control area has seen no notable change in Emu activity levels during the monitoring program. Similar in Section 4, while data has only been collected during construction, these records show continued and regular Emu occupation despite construction activity.

As Emus are nomadic and move in response to the availability of resources, a decline in activity at a location may not reflect a decline in population density rather this may be associated with individual birds moving through the landscape and away from the monitoring locations and associated with either breeding movements or resource availability or both. This is reflected by the data gathered as illustrated in Figure 14 which shows the pooled trap activity data across 5 years (before and after) according to season at both impact and control areas. The increase in Emu activity for control areas in winter and spring is related to the sites in Yuraygir north that occur in proximity to sugar cane properties and suggests these are important during breeding periods, this trend is also seen the construction sighting register in Section 4. Conversely while impact areas have lower density, these appear more important in summer and autumn outside the breeding period. There are no cane farms in Section 3.

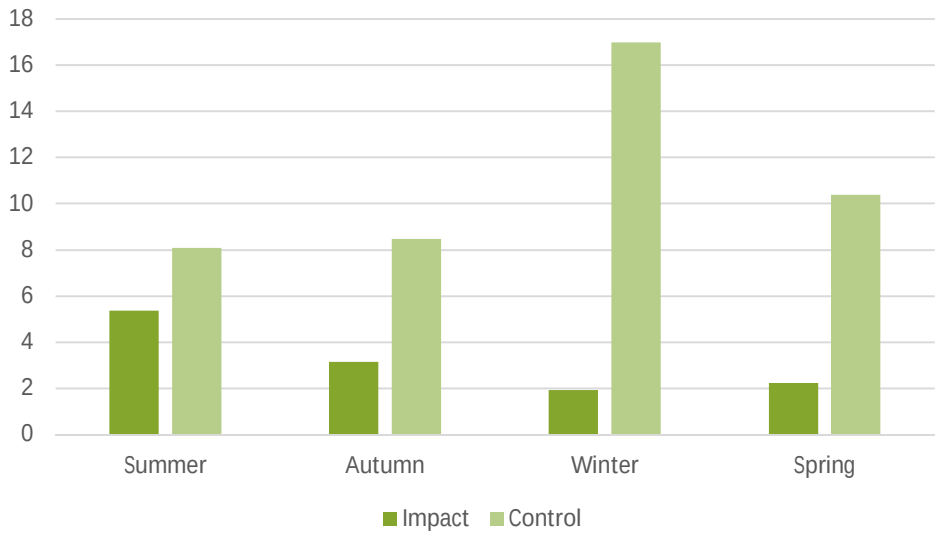

Figure 14: Comparison of seasonal camera trap rates (mean no. Emu photographed per 100 trap days) over 5 years at impact and control study areas

4.2 Effectiveness of mitigation measures

Three key construction mitigation measures documented in the Emu Management Plan were implemented in the monitoring period. This includes 1) the installation of temporary and permanent fencing in important Emu areas, 2) the installation of Emu races to maintain active crossing zones during construction and 3) the collection of data on Emu sightings during construction.

There was evidence showing at least one Emu race was used for crossing the corridor during construction, and there were no Emu mortalities reported during construction due to poor or absent fencing. From this perspective, the mitigation measures are deemed to be effective. This is in large part to the measures applied to minimise impacts to Emus when encountered on the road corridor, which occurred on multiple occasions.

It has been difficult to effectively monitor the Emu races during construction in 2018 and this is directly a result of the very high level of construction activity and lower chance of detecting Emus. As a result, it is possible that Emus have used a race in 2018 and this has not been detected. The effectiveness is expected to increase from late 2019 when construction activity reduces. Despite the issues with the crossing zones, Emus were recorded both east and west of the project corridor during construction, it is unknown whether these were birds moving across the corridor or have remained on one side only.

4.3 Performance measures

The Emu Management Plan documents a set of goals associated with managing Emus and respective impact thresholds to be considered during monitoring. Where a threshold is not achieved, corrective actions are required. This applies to the both the W2B construction phase as well as the longer-term project monitoring program. Discussion on the reported outcomes from the construction stage monitoring in 2017 and 2018 and recommended corrective actions where required is provided in Table 10.

Table 10. Appraisal of the reported outcomes of construction phase monitoring against the performance thresholds documented in the Emu Management Plan

Main goals for management	Management measure	Performance thresholds	Reported outcomes in 2018 annual report	Corrective actions if performance threshold not reached
No injuries to Emus during clearing of vegetation.	• Documented procedure for clearing of vegetation. • Documented procedure for emergency management if Emu is encountered during clearing works. • Procedure developed in consultation with WIRES and NPWS. • Project ecologist evaluates situation and approach on each occasion.	Emu injured or killed during clearing works.	Ecologists were used during clearing operations in Section 3 and 4 in 2017. No Emus were reported injured or killed	No corrective actions were required
No injuries to Emus from collisions with construction vehicles.	• All vehicles to stay within the construction corridor and no entry into exclusion zones. • Comply with construction vehicles speed limits designated in the CEMP. • Implement a daily inspection of Emu crossing zones and fence integrity. • Comply with protocol developed for Wave 3 early works (Section 4) Section 5.3.2	• Emu injured during construction. • Single Emu sighted in Wave 3 early works corridor during construction • 3 Emu encounters in one day	A register of Emu sightings has been maintained from 2016-2018, while Emus were reported in the construction corridor on 9 occasions, management measures were implemented and there were no reported injuries or mortalities	No corrective actions were required
No damage to Emu habitat within exclusion zones in Section 3 and 4 during construction.	• Implement the Emu fencing strategy prior to construction. • Fencing to be erected concurrently with clearing procedure in Section 3 and 4.	Breach in exclusion zone by construction vehicle of personnel.	Temporary and permanent exclusion fences were completed concurrently with the clearing procedure.	No corrective actions were required
No change in pre-construction Emu movements across the construction corridor.	• Adopt Emu fencing strategy • Construction infrastructure and access tracks located to avoid lengthy interruption to Emu movements. • Avoid extended activities in or adjacent to known Emu habitat, watering points or crossing zones. • As soon as bridge construction completed, bridge to be tied in with exclusion fence and site remediated to open the crossing zone. • Provide and maintain an Emu race across 9 crossing zones between Wooli Road and south of Firth Heinz Road, to be opened outside of work hours	After four construction monitoring events there is a demonstrated change from pre-construction Emu movements across the project corridor.	There have been 8 construction monitoring events (2017 and 2018). Emu races have been maintained across 8 crossing zones during construction. Bridges were not opened. It has been difficult to effectively monitor the Emu races during construction in 2018 and this is directly a result of the very high level of construction activity and lower chance of detecting Emus. As a result, it is possible that Emus have used a race in 2018 and this has not been detected. The effectiveness is expected to increase from late 2019 when construction activity reduces	The monitoring methodology for the Emu races has been continually evaluated and revised to improve captures of Emus. This technique is likely to remain compromised until construction activity slows, and there are no corrective actions required

Main goals for management	Management measure	Performance thresholds	Reported outcomes in 2018 annual report	Corrective actions if performance threshold not reached
			Emus have been reported east and west of the construction corridor during the construction phase monitoring, however declines in activity have been noted in the Pillar Valley west study area.	
Cover crops established within 3 months of completion of the bridge construction in Section 3 and 4.	Implement revegetation and rehabilitation to commence immediately on completion of construction activity completion and to be staged to avoid lengthy disruption to Emu movement corridors.	Event based, incident reporting in CEMP	Some minor planting of riparian vegetation has commenced in Section 3 in 2018 however bridge construction has not finished.	Commence revegetation in crossing zones where bridge construction is complete in 2019 Monitor survivorship of plantings and replace where necessary until established
Methods for rehabilitation of Emu habitat adjacent to the road is documented in the landscape design.	• Roadside plantings in Emu habitat (Section 3 and 4) avoid Emu food plants to prevent Emus being attracted to road edges. • Landscape plantings under Emu crossing zones in Section 3 and 4 to use native grasses or low ground covers suitable to the location and avoid dense plantings of trees and shrubs. • Revegetation in roadside areas disturbed during construction to restore the original habitat type at each location.	Evidence of Emu specific revegetation to be captured in the landscape design.	Not proposed in the first year of construction	No corrective actions required

Discussion on the reported outcomes from the construction stage monitoring in 2018 and recommended corrective actions where this relates to the longer-term Emu population monitoring is provided in Table 11.

Table 11. Appraisal of the reported outcomes of construction phase monitoring against the performance thresholds documented in the Emu Management Plan for the longer-term monitoring program

Performance thresholds	Timing and corrective actions	Reported outcomes
• Greater than 15% decline in Emu activity (through signs and detection rates) comparing impact and control areas and before and after data. • No evidence of breeding through sightings of chicks and sub-adults between impact and control areas and before and after data.	• The 15% threshold was set prior to conducting baseline surveys. It will be necessary to review this trigger against pre-construction data to identify normal changes in activity that are occur over time irrespective of the highway disturbance. The threshold would be reviewed and revised where required at the end of the pre-construction monitoring. • Emu activity would be compared with the baseline data at the end of each monitoring event during the construction phase. Regular evaluation and review would be conducted at the end of each monitoring event. • If decline noted after the first 12 months of the post-construction (operational) monitoring, review and modify the monitoring program, to consider different monitoring locations. • Review transects locations and cross reference with performance monitoring of the Emu crossing structures and fencing strategy. • Investigate Emu habitat adjoining the highway and consider improving habitat condition and connectivity. • If decline still noted after a further 12 months operational monitoring (2-years operation) engage with EPA and consider provisional measures. • Further monitoring of provisional measures would be planned at this stage.	• Monitoring has shown a decline in Emu activity that is consistent in Section 3 as well as the southern control area, in contrast to continued Emu activity in Section 4 and the northern control area. When comparing the occupation of Emus between the pre-construction and construction phases there has been 21 % decline in impact areas compared with 34 % decline in control areas • Evidence of breeding was noted in Section 4 through multiple observations of juvenile birds during 2017-2018 as reported in the Emu sightings register • Data from 13 pre-construction surveys showed a decline of 30 % in impact sites (prior to construction) and 55% in control sites (prior to construction). • The indicative 15% threshold should be revised to a minimum of 30%. • No corrective actions required at this stage because there is evidence that the declines have occurred consistently since the pre-construction phase and across impact and control areas and the declines are within the threshold determined by the pre-construction surveys.

4.4 Annual citizen-based emu survey

The NPWS coordinated annual citizen-based Coastal Emu survey was not conducted in 2017 or 2018 due to other responsibilities. However, NPWS did collate emu sightings data provided by landholders, surveillance cameras (RMS and NPWS) and opportunistic sightings in 2017. From analysis of these data the following has been noted (G.Hart, NPWS; *pers.comm*):

There appears to have been further contractions in their range and a decline in the Clarence population over the last couple of years (47 recorded in the Clarence in 2016). The reasons for this remain unclear, however the following observations have been drawn from the 2017 data collected:

- larger groups of birds not being seen on cane farms around the Shark Creek area possibly due to some of the cane farmers not planting soy crops this year as part of their crop rotation.
- No adults or chicks seen around Minnie Water, Wooli area since late 2014. This has historically been the hotspot for emu sightings. My personal thoughts were that longer fire intervals in the coastal landscape may have been impeding the movement of the birds. However, there has been a relatively large area around Diggers and Wooli burnt in last 18 months, yet still no birds recorded. There have however been sightings in northern Yuraygir in areas recently burnt in a wildfire earlier this year.
- No birds seen in the Pebbly Beach / Station Creek area since 2011.
- Sightings along the new highway route south of Tyndale have declined since construction commenced earlier this year

Relative population data reported from the annual citizen survey of coastal emus is show in **Figure 15** and has been divided into the three main sub-populations (Bundjalung, Yuraygir, and Bungawalbin). These data report the actual number of emus observed over the two-day survey and not individuals observed before or after the survey or sign data. The data is only intended to provide a relative abundance estimate and is not based on total counts. This is because the survey is largely restricted to road areas, the number of observers and hence survey effort varied from year to year and also emus are widespread and difficult to count.

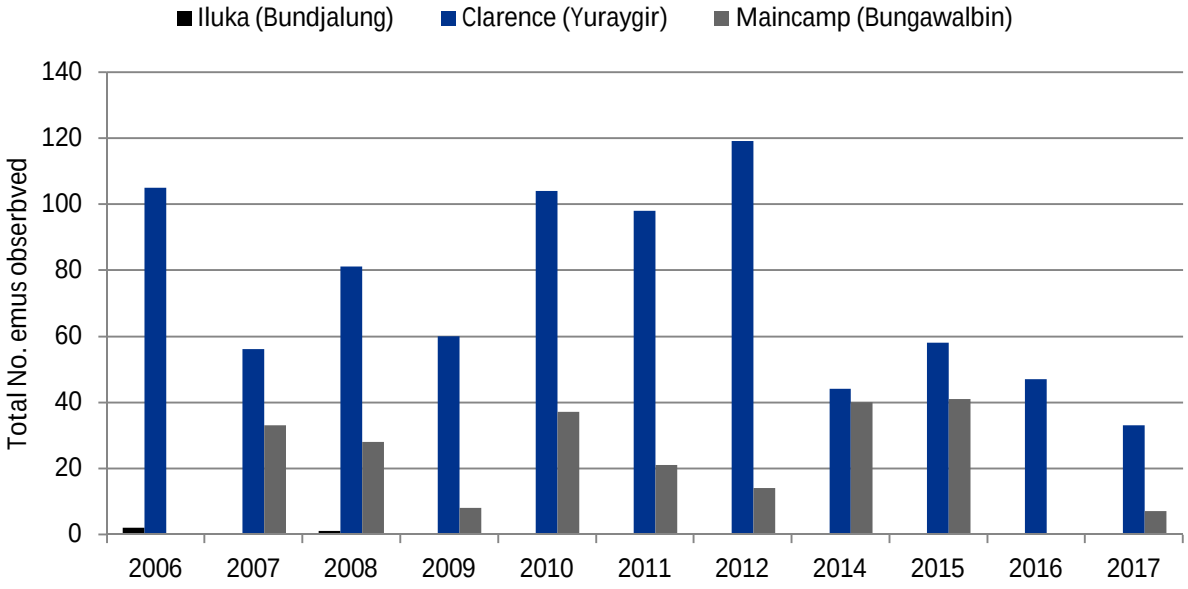

Figure 15: Relative population data collated from the annual coastal emu citizen survey (2006-2017 source: Office of Environment and Heritage)

4.5 Recommendations

Corrective actions are not deemed to be required. The complete absence of emu presence from the five Yuraygir south transects raises important questions around the local movements of Emus. There is value in maintaining the baseline transects and also adding additional sections of transect to increase the search effort as part of an adaptive monitoring approach. This may provide insight into presence of emus adjacent to transect areas and explain false negatives. Any emu activity identified on new transect sections would be reported separate to the comparison with baseline surveys.

Table 12. Recommendation following Year 2 coastal emu monitoring and Roads and Maritime response.

No.	Recommendation	Roads and Maritime response
1	Adapt the monitoring effort in the southern control area, to include a new transect and addition section of transect in 2019	Adopted: may be of benefit to understand movements and absences of emus from some locations.

5. References

Roads and Maritime Services, (2016). Woolgoolga to Ballina, Pacific Highway Upgrade, Coastal Emu Management Plan. Prepared by RMS, and SKM.

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Jacobs (2017), Pacific Highway Upgrade Woolgoolga to Ballina Coastal Emu Monitoring Program: Annual Report 2017 (Construction Year 1)

Underwood, A.J. (1991). Beyond BACI: Experimental designs for detecting human environmental impacts on temporal variations in natural populations. Australian Journal of Marine and Freshwater Research 42(5) 569-587.

Appendix A. Summary of Emu sign data (Density/ha)

SAMPLING PERIOD	IMPACT SITES						CONTROL SITES			
	Pillar Valley west		Tucabia south		Tucabia north		Yuraygir south		Yuraygir north	
	PRE-CONST	CONSTR	PRE-CONST	CONST	PRE-CONST	CONST	PRE-CONST	CONST	PRE-CONST	CONST
1	2.56	0.32	6.52	6.52	0.00	0.57	5.53	0	1.28	5.77
2	3.68	0.96	9.78	4.78	0.00	0.57	4.42	0	5.13	4.49
3	3.52	0.32	5.87	3.48	3.22	0.19	3.87	0	4.81	2.88
4	6.40	0.16	1.74	1.30	1.52	0.57	4.61	0	11.54	4.17
5	5.60	0.48	1.96	1.09	3.22	0.19	0.92	0	14.74	1.28
6	2.56	0.48	7.61	0.43	0.95	0.38	0.18	0	7.37	1.60
7	0.80	0.00	5.87	1.74	0.19	0.00	0.00	0	4.81	3.53
8	2.24	0.00	3.26	0.87	0.00	0.38	0.00	0	3.85	1.92
9	1.92		3.48		0.19		0.00		5.77	
10	0.96		2.61		0.00		0.00		4.81	
11	0.64		3.26		0.19		0.00		2.88	
12	1.44		1.52		0.19		0.00		5.13	
13	1.28		2.17		0.00		0.00		6.73	
mean	2.58	0.34	4.28	2.53	0.74	0.36	1.50	0.00	6.07	3.21
SE	0.50	0.11	0.72	0.77	0.33	0.08	0.61	0.00	0.99	0.56

Appendix B. Summary of site occupation during construction

Table C1. Site occupancy rates recorded for Year 1 (2017) and Year 2 (2018) of construction from combined sign and camera trapping data (1 = site occupied, 0 = absent)

Study area	Site	Treatment	Year 1 (2017)				Year 2 (2018)			
			Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring
Pillar Valley west	PVA	Impact	0	0	0	0	0	0	0	0
	PVB	Impact	0	0	0	0	0	1	0	0
	PVC	Impact	1	1	1	1	1	0	0	0
	PVD	Impact	1	1	1	1	1	0	0	0
Tucabia south	MRA	Impact	1	1	1	1	1	1	0	1
	MRB	Impact	1	1	1	1	1	1	1	1
	MRC	Impact	1	0	1	1	0	0	0	0
	MRD	Impact	1	0	1	0	0	0	0	0
	MRE	Impact	0	1	0	0	0	0	0	0
Tucabia north	TNA	Impact	1	0	0	0	0	0	0	0
	TNB	Impact	0	0	0	0	0	1	0	0
	TNC	Impact	0	1	1	0	1	0	0	1
	TND	Impact	1	1	1	1	1	1	0	0
Yuraygir north	YNA	Control	1	1	1	1	1	1	1	0
	YNB	Control	1	1	1	1	1	1	1	1
Yuraygir south	YSA	Control	0	0	0	0	0	0	0	0
	YSB	Control	0	0	0	0	0	0	0	0
	YSC	Control	0	0	0	0	0	0	0	0
	YSD	Control	0	0	0	0	0	0	0	0
	YSE	Control	0	0	0	0	0	0	0	0
Occupancy rate (impact)			61.5	53.8	61.5	46.2	46.2	38.5	7.7	23.1
Occupancy rate (control)			28.6	28.6	28.6	28.6	28.6	28.6	28.6	14.3

Appendix C. Construction monitoring data at Emu crossing zones (Section 3)

Table D1. Details and results of camera traps placed on Emu crossing zones during construction (2017-18)

Monitoring period	Crossing zone	Camera	Position	Start date	End date	No. functional camera days	No. photos	No. Emu photos	Other fauna using race
C2 (Autumn 2017)	T1	1	East	21/02/2017	20/04/2017	58	4159	0	1 dog
		2	East	21/02/2017	1/05/2017	69	462	0	
		3	West	21/02/2017	17/03/2017	24	3635	0	
		4	West	21/02/2017	7/03/2017	14	2286	0	
	T4B	1	East	21/02/2017	23/05/2017	91	655	1 (Plate 9)	
		2	West	21/02/2017	malfunction	0	0	0	
	T6	1	East	21/02/2017	22/02/2017	1	335	0	
		2	West	21/02/2017	3/03/2017	10	4903	0	
		3	Mid	21/02/2017	23/05/2017	91	2068	0	
C3 (Winter 2017)	T1	1 to 4	removed for construction of piling pads			0	0	0	
	T2	1	East	23/05/2017	22/08/2017	91	2205	0	
		2	East	23/05/2017	22/08/2017	91	936	0	
		3	West	23/05/2017	15/06/2017	23	3797	0	
		4	West	23/05/2017	14/07/2017	52	2324	0	
	T4B	1	East	23/05/2017	22/08/2017	91	526	0	
		2	West	23/05/2017	22/08/2017	91	485	0	
	T6	1	East	23/05/2017	22/08/2017	91	405	0	
		2	West	23/05/2017	28/06/2017	36	5913	0	
		3	Mid	23/05/2017	22/08/2017	91	3800	0	
C4 (Spring 2017)	T1	1	East	21/08/2017	22/09/2017	32	4105	0	Cattle
		2	East	21/08/2017	7/11/2017	78	7719	0	
		3	West	21/08/2017	5/09/2017	15	5052	0	Cattle
	T2	1	East	21/08/2017	7/11/2017	78	917	0	Cattle and kangaroos
		2	West	21/08/2017	malfunction	0	0	0	
	T4A	1	East	22/08/2017	9/10/2017	48	4964	0	
		2	West	22/08/2017	29/10/2017	68	2140	0	
	T4B	1	East	21/08/2017	24/08/2017	3	1090		
		2	West	21/08/2017	7/11/2017	78	311	0	Cattle
	T5	1	East	21/08/2017	7/11/2017	78	2239	0	Cattle and kangaroos
		2	West	21/08/2017	20/10/2017	60	9077	0	Cattle and kangaroos
	T6	1	East	22/08/2017	8/11/2017	78	499	0	
		2	West	22/08/2017	5/10/2017	44	3081	0	
		3	Mid	22/08/2017	27/10/2017	66	1232	0	
	T9	1	East	21/08/2017	7/11/2017	78	283	0	Cattle and kangaroos
		2	West	21/08/2017	30/09/2017	40	1977	0	Cattle and kangaroos
	T10	1	East	22/08/2017	5/10/2017	44	901	0	

Monitoring period	Crossing zone	Camera	Position	Start date	End date	No. functional camera days	No. photos	No. Emu photos	Other fauna using race
		2	West	22/08/2017	25/10/2017	64	1924	0	
C5 (Summer 2018)	T1	1	East	removed during construction		0	0	0	
		2	West	7/11/2017	6/02/2018	91	46666	0	
	T2	1	East	7/11/2017	12/02/2018	97	2143	0	
		2	West	7/11/2017	12/02/2018	97	1272	0	
	T4A	1	East	removed during construction		0	0	0	
		2	West	7/11/2017	6/02/2018	91	106	0	
	T4B	1	East	6/11/2017	12/02/2018	98	280	0	Cattle
		2	West	6/11/2017	12/02/2018	98	16	0	Cattle
	T5	1	East	6/11/2017	13/02/2018	99	459	0	Cattle
		2	West	malfunction - no data		0	0	0	
	T6	1	East	6/11/2017	12/02/2018	98	3081	0	
		2	West	6/11/2017	12/02/2018	98	1232	0	
	T9	1	East	6/11/2017	12/02/2018	98	368	0	Cattle and kangaroos
		2	West	6/11/2017	12/02/2018	98	2038	0	Cattle and kangaroos
	T10	1	East	6/11/2017	12/02/2018	98	9	0	
		2	West	6/11/2017	12/02/2018	98	53	0	
C6 (Autumn 2018)	T1	1	East	1/01/2018	18/02/2018	49	3645	0	Cattle
		2	West	13/02/2018	22/05/2018	98	199	0	
	T2	1	East	13/02/2018	22/05/2018	98	1226	0	
		2	West	13/02/2018	21/04/2018	67	996	0	
	T4A	1	East	13/02/2018	27/03/2018	24	2871	0	
		2	West	Stolen		0	0	0	
	T4B	1	East	14/02/2018	22/05/2018	97	3270	0	Cattle and kangaroos
		2	West	16/02/2018	9/04/2018	52	382	0	Cattle and kangaroos
	T5	1	East	13/02/2018	20/05/2018	96	289	0	
		2	West	13/02/2018	20/05/2018	96	1339	0	
	T6	1	East	Missing data		0	0	0	
		2	West	Missing data		0	0	0	
	T9	1	East	13/02/2018	20/05/2018	96	182	0	
		2	West	13/02/2018	3/03/2018	18	2034	0	
	T10	1	East	13/02/2018	22/05/2018	98	133	0	
		2	West	13/02/2018	13/02/2018	1	62	0	
C7 (Winter 2018)	T1	1	East	22/05/2018	28/08/2018	98	346	0	
		2	West	22/05/2018	28/08/2018	98	515	0	
	T2	1	East	22/05/2018	28/08/2018	98	1166	0	Cattle and kangaroos
		2	West	22/05/2018	28/08/2018	98	305	0	
	T4A	Temporary crossing that is now closed. “T4B” will now be referred to as “T4”							
	T4	1	East	22/05/2018	28/08/2018	98	157	0	
		2	West	22/05/2018	24/07/2018	63	1443	0	

Monitoring period	Crossing zone	Camera	Position	Start date	End date	No. functional camera days	No. photos	No. Emu photos	Other fauna using race
	T5	1	East	22/05/2018	28/08/2018	98	815	0	
		2	West	22/05/2018	28/08/2018	98	149	0	
	T6	1	East	22/05/2018	28/08/2018	98	4997	0	
		2	West	22/05/2018	28/08/2018	98	57	0	
	T9	1	East	22/05/2018	17/08/2018	87	27	0	
		2	West	22/05/2018	28/08/2018	98	1972	0	
	T10	1	East	22/05/2018	28/08/2018	98	82	0	
		2	East	22/05/2018	28/08/2018	98	310	0	
		3	West	22/05/2018	28/08/2018	98	29	0	
C8 (Spring 2018)	T1	1	East	28/08/2018	6/11/2018	70	2213	0	Cattle
		2	West	28/08/2018	6/11/2018	70	553	0	
	T2	1	East	28/08/2018	6/11/2018	70	27	0	Cattle and kangaroos
		2	West	28/08/2018	6/11/2018	70	38	0	
	T4B	1	East	28/08/2018	6/11/2018	70	1	0	
		2	West	28/08/2018	6/11/2018	70	4173	0	
	T5	1	East	28/08/2018	6/11/2018	70	660	0	
		2	West	28/08/2018	6/11/2018	70	70	0	Cattle and kangaroos
	T6	1	East	28/08/2018	26/10/2018	58	2494	0	
		2	West	28/08/2018	6/11/2018	70	6	0	
	T9	1	East	28/08/2018	6/11/2018	70	1070	0	Cattle
		2	West	28/08/2018	1/11/2018	65	2066	0	Cattle and kangaroos
	T10	1	East	28/08/2018	13/09/2018	16	928	0	
		2	West	28/08/2018	6/11/2018	70	127	0	