Woolgoolga to Ballina Pacific Highway upgrade

Coastal Emu Monitoring Program

Annual Report 2021

Operation Phase (Year 1)

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Woolgoolga to Ballina Pacific Highway Upgrade

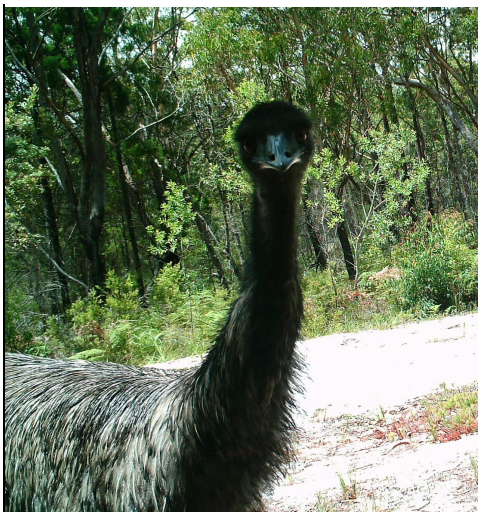
Coastal Emu Monitoring Program – Annual Report 2021

Year 1 Operation

Final

14 December 2022

Transport for NSW



W2B Biodiversity Monitoring

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1. Introduction

1.1 Background and objectives

The Pacific Highway upgrade from Woolgoolga to Ballina (W2B) 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). The Plan outlines objectives and a methodology for conducting a monitoring program to monitor the effectiveness of mitigation measures planned for Coastal Emus (*Dromaius novaehollandiae*). The monitoring 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 any adaptive mitigation measures 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 outlined 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 over 13 monitoring events and the results reported in three pre-construction phase 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. Completion of the construction phase monitoring ended in May-June 2021 and operation of the highway in section 3 and 4 commenced in June 2020. This report outlines the methods and results of Emu monitoring in year 1 of the operational phase Q2&3 2020 and Q1&2 2021 with the inclusion of data from two sampling periods in the year 2 operational phase Q3&4 2021.

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 the effectiveness of mitigation measures and ongoing monitoring. The program is based on a BACI approach (Before, After, Control, Impact), monitoring Emu presence at impact sites in proximity to the highway and control sites in coastal areas to the east of the highway. The program compares the 3-year baseline dataset with monitoring data collected seasonally during construction and operational monitoring and will continue for five years after opening 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 are 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

identified likely Emu crossing zones (heightened bridges). Control sites were selected in coastal forest and grassland habitats which resemble the impact sites and are expected to have regular Emu presence, all sites are greater than 15 km from the project. 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. Temporary fencing and emu crossing zones were found to be effective, and the results are reported in Jacobs (2017).

Monitoring of a subset of the Emu crossing zones continued during construction where purpose-built Emu races were provided to monitor if emus were able to cross the construction corridor. A number of raised bridge structures have been constructed at Emu crossing zones to facilitate crossing below the highway during operation. These structures are combined with permanent exclusion fencing and will be monitored during operation in conjunction with emu occupation surveys east and west of the project corridor.

Operational phase monitoring has incorporated a program to monitor eighteen bridge structures within Section 3 and Section 4 of the highway and the adjacent exclusion fences to determine the effectiveness of these mitigation measures for facilitating movements of Emus across the highway corridor.

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. Methods

2.1 Site occupation surveys

2.1.1 Study area

Monitoring Emu site occupancy commenced in 2013 and has continued at impact and control sites focused on five survey areas:

1) Pillar Valley west (PV), including land east and west of the Tucabia-Tyndale Road and portions of the Coldstream River floodplain, 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 floodplain (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).

2.1.2 Survey transects

The intent of the sampling is to monitor Emu presence/absence over time within each of these survey areas relative to the different project phases (pre-construction, construction and operation) rather than a comparison between areas. This is achieved by repeat sampling of between 2 and 5 transects in each survey area using transects that range between 800 and 2000 metres in length. In total 24.7 km of transects are sampled from 13 impact sites and 7 control sites (Table 2.1). Sites were stratified to sample a range of different habitat types including pastoral land, forest, riparian, and wetland areas. The location of survey areas is shown on Figure 1 and the location of impact transects in relation to the highway corridor and bridge locations is shown on

Figure 2.

As the Emu population in the study area is small and occupies large areas, the absence of emu sign from a transect over time may not necessarily reflect the absence of emus in the study area, but rather a shift in emu activity away from the transect. To account for this, transects are occasionally modified to improve the detectability of emus. This may also occur where access permission to private property has changed over the course of the program. This has included extending transect lengths, combining transects and in some cases, adding new transects. Where this has occurred, effort has been made not to distort the integrity of the data by keeping transects in the same proximal area and similar transect lengths and search areas.

Table 2.1: Study areas, survey sites and details of Emu monitoring transects

Survey area	Transect	Status	Habitat	Transect length (m)	Search area (ha) based on 10 m transect width	Transect position relative to road	Adaptive monitoring approaches
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	Shifted start of transect to neighbouring property to east in 2020
	PV-D	Impact	Grazing / forest	2425	2.42	East	
			Total	*6220 m*	*6.2 ha*		

Survey area	Transect	Status	Habitat	Transect length (m)	Search area (ha) based on 10 m transect width	Transect position relative to road	Adaptive monitoring approaches
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	Shifted 300 m south to new fence line in 2019
	MR-E	Impact	Open forest	1400	1.40	East	Shifted 200 m to the north from easement to riparian corridor in 2019
			Total	*4645 m*	*4.6 ha*		
Tucabia North (TN)	TN-A	Impact	Open forest	2080	2.08	West	
	TN-B	Impact	Open forest / wetland	645	0.64	West	
	TN-C	Impact	Open forest	1365	1.36	East	Start of transect moved to edge of new road in 2018
	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	-	Transect extended further 500 m
	YS-C	Control	Open forest	1030	1.03	-	
	YS-D	Control	Open forest	730	0.73	-	Original YS-D and YS_E combined in 2019
	YS-E	Control	Open forest	1250	1.25	-	YS-E changed to new location
			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*		

Legend

- Approved Project Boundary
- Survey transects
- State Forest
- NPWS Reserve

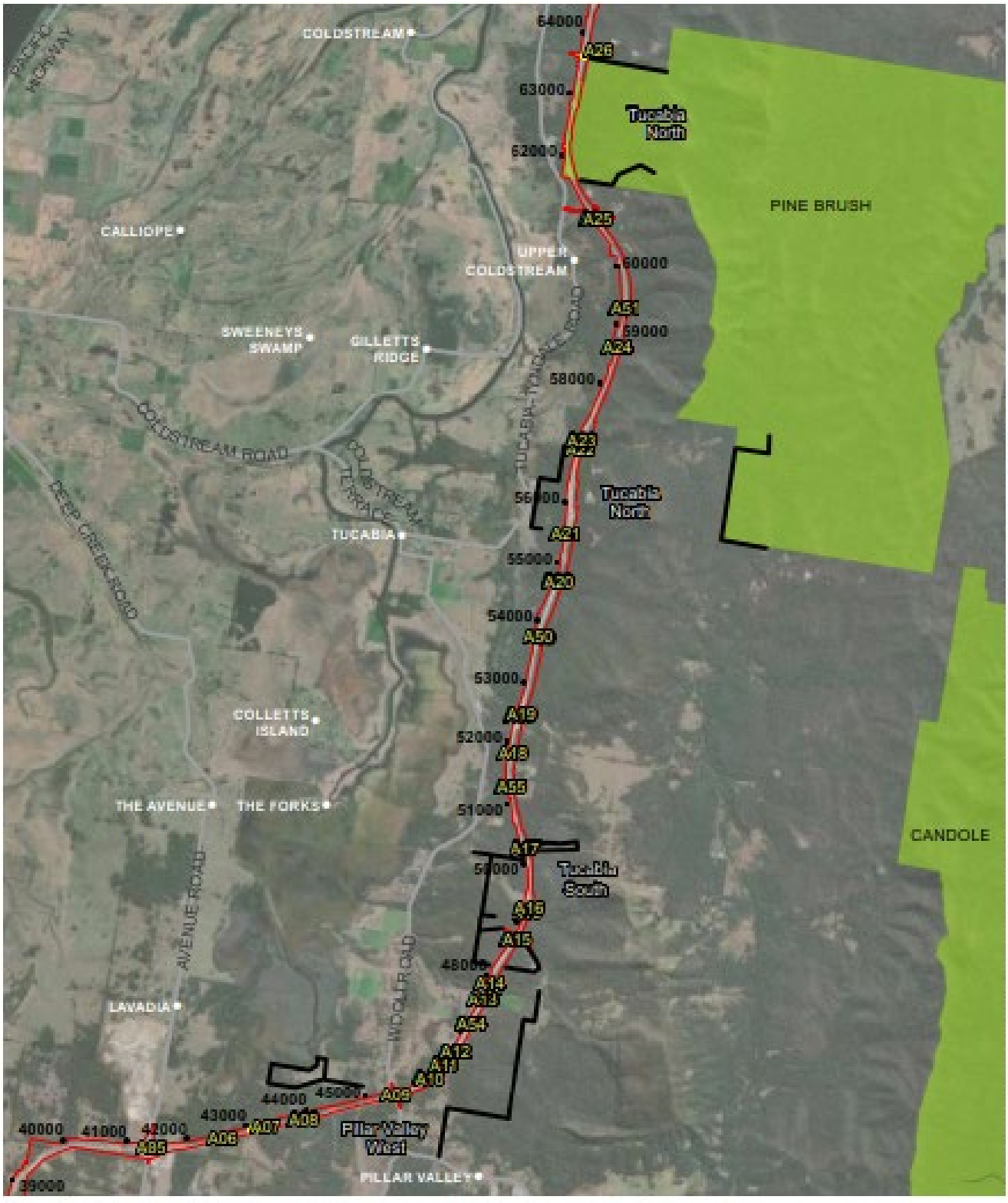
1:350,000 @ A4

0 6 12 km

Data sources

Jacobs 2017, Pacific Complete 2017, LPI 2017, Imagery Service Layer Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 1 | Coastal Emu monitoring survey areas



Legend

Approved Project Boundary

State Forest

Impact transects

Bridge sites

1:110,000 @ A4

0 2.5 5 km

Data sources

Jacobs 2017, Pacific Complete 2017, LPI 2017, Imagery Service Layer Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 2 | Impact Transects

2.1.3 Timing

Monitoring of the spatial and temporal presence/absence of Emus relied on two methods centred on each transect and included 1) searches for Emu signs and 2) camera trapping. Sign searches and the download of photographs from camera traps is conducted at four quarterly events targeting the last week 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. Travel restrictions due to covid lockdown affected sampling in the winter period of 2021 (OP5). Transect and crossing structure surveys were not able to be conducted and any impact of this on the sign and camera data is discussed in the subsequent results of this report.

2.1.4 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 sign 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

2.1.5 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 (Stealth Cam GN45), triggered by motion sensors, to 'trap' images of passing Emus. Up to two camera traps were maintained semi-systematically along each transect, to provide a total of between 4-12 cameras per survey 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 in a new location.

Details on camera trapping effort during each project phase are summarised in Table 2.2. The summary data shows a comparison of the trap effort during the construction years 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 has been comparable across each survey 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 (quarterly) as discussed previously in timing. Broken, malfunctioning and stolen cameras are replaced as required during each quarterly inspection.

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 monitor changes in dog activity around crossing zones.

Visits to the site for the end of winter monitoring period in 2021 was not able to be attended due to Covid lockdown and travel restrictions in the region. This impacted camera success and trapping days in the spring 2021 survey period (Aug-Nov 2021), as camera batteries were not able to be updated at the end of August. However, as camera success was high in the first stages of the operational monitoring, the total camera trapping effort has remained comparable between the pre-construction, construction, and operational phases of the monitoring program (Table 2.2).

Table 2.2: Summary and comparison of camera trapping effort during the course of the monitoring program

Sampling period	Survey effort	Impact areas			Control areas	
		Pillar Valley	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 (mean)	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*
Construction (data shown is the means recorded over 14 quarterly monitoring sessions.	Camera monitoring days per season	91.1	91.1	91.1	91.1	91.1
	No. successful cameras (mean)	6.4	9.6	6.9	3.6	7.4
	Mean trapping days per camera	72.4	79.2	78.4	78.9	73.8
	Total camera trap effort (days)	*473.3*	*773.7*	*584.8*	*370.9*	*543.2*
Operation (data shown is the mean recorded over 6 quarterly (seasonal) monitoring periods	Camera monitoring days per season	91.0	91.0	91.0	91.0	91.0
	No. successful cameras	5.8	9.8	7.7	3.5	8.8
	Mean trapping days per camera	81.2	81.1	77.2	76.2	86.5
	Total camera trap effort (days)	*525.0*	*802.2*	*627.7*	*327.5*	*828.2*

2.2 Monitoring crossing zones

2.2.1 Bridge structures

Potential highway crossing zones (bridges) and exclusion fencing targeted at Emus have been provided between chainage 42.500 and 74.500 (Section 3 and 4 of the project) and include:

- Raised bridges with a minimum height of 3.6 metres and a minimum width of 4 metres of dry passage retained along both banks of the creek channel and abutments
- Purpose built exclusion fencing strategically located in areas surrounding the crossing structures to direct emus to the structure, and elsewhere in emu habitat areas to prevent emus from entering the highway corridor.

According to the Emu Management Plan, the monitoring program is to be designed to compare a range of these crossing types to determine their effectiveness at allowing emu passage across the road and inform management decisions, this would include:

- Structure type (raised versus non-raised (standard) bridges)
- Landscape type surrounding the structure (riparian habitat, cropping land, open grazed landscapes, and structures with landscape plantings added)
- Attractant type (cleared easement or tracks leading to bridge, and no attractants)

Thirty (30) potential crossing locations are identified in the Coastal Emu Management Plan (Table 5-1), this included 21 bridges over creeks, drains and floodplain and 9 incidental structures such as road overpasses, property access and culverts which may potentially be used by emus to cross the highway. From these, the operational monitoring focuses on 18 bridge structures in locations where emus have historically been recorded between the Coldstream River in the south (Section 3), north to Shark Creek (Section 4). Structures to be monitored have been selected to maximise the chance of recording emus on motion detection cameras, considering bridge location relative to landscape / habitat, comparing structure size and attractants, as follows

- Of the 18 structures, 14 of these have been designed with a minimum 3.6 m clearance from ground (raised bridges). Bridges in Section 3 of the project were raised above their functional requirements to allow for

emu passage, and 4 bridges retained a standard functional design, that were not designed specifically for targeting emu passage (non-raised bridges).

- A range of landscape and habitat types was selected for monitoring, including Swamp Forest (2 sites), Dry Forest (3 sites), Riparian Forest (2 sites), Grazing Land (4 sites), Cropping Land (3 sites), and mixed forest and grazing land occurring east and west of the structure (4 sites).
- There are no sites with obvious tracks or attractants secured or leading to a bridge structure, although 18 sites have used landscape plantings below the bridge targeting emu food plants and this has been considered an attractant for the purpose of monitoring usage. Consideration of additional attractants may occur as the program progresses and if structures are found not to be effective.
- Four sites comprise rural stock fencing parallel with and below the road and bridge, which is used for excluding cattle entering different property owners on both sides of the highway, or selective exclusion of cattle from un-grazed areas. These are referred to as 'Emu Hybrid Fencing' and have been designed as 4 strand fences with adequate spacing to allow emu passage but exclude cattle, and two of these sites have included an 'Emu Gate' as part of the hybrid fence design.

Details of the structures selected for the operational phase monitoring are presented in Table 2-4.

Table 2.3: Details of bridges monitored the operational phase of the highway (* identifies Emu / Cattle hybrid fence is associated with structure)

Site ref No.	Design ref	Project section (Chainage)	Waterway	Landscape/ Habitat type	Bridge / site specifications and monitoring details	Design raised for emu passage	Emu food plants used in landscaping^	No. cameras (camera id)
A	Bridge A08	S3 (43.881)	None, floodplain	Swamp forest	200 m x 3.6 m ground clearance dual carriageways with opening between bridges. Exclusion fencing adjoining. Monitoring commenced end of 2nd Quarter 2020 (26.05)	Yes	Yes	5 (A1-A5)
B	Bridge A10	S3 (46.325)	Pillar Valley Creek.	Swamp forest	80 m x 3.6 m ground clearance dual carriageways with opening between bridges. Exclusion fencing adjoining. Corresponds with T1 construction monitoring site. Monitoring commenced end of 2nd Quarter 2020 (26.05) two cameras.	Yes	Yes	4 (B1-B4)
C	Bridge A11	S3 (46.342)	Pillar Valley Creek	Grazing land	93 m x 3.6 m ground clearance dual carriageways with opening between bridges. Exclusion fencing adjoining. Corresponds with T2 construction monitoring site. Monitoring commenced end of 2nd Quarter 2020 (26.05) two cameras.	Yes	Yes	4 (C1-C4)
D	Bridge A12	S3 (46.628)	Black Snake Creek	Grazing land	60 m x 3.6 m ground clearance dual carriageways with opening between bridges. Exclusion fencing adjoining. Corresponds with T3 construction monitoring site. Monitoring commenced end of 2nd Quarter 2020 (26.05) one camera, then second camera 25.08.2020.	Yes	Yes	2 (D1, D2)
E	Bridge A54	S3 (47.190)	None, floodplain	Grazing land	20 m x 3.6 m ground clearance dual carriageways with opening between bridges. Exclusion fencing adjoining. Corresponds with T4 construction monitoring site. Monitoring commenced end of 2nd Quarter 2020 (26.05) two cameras.	Yes	No	2 (E1, E2)
F	Bridge A13	S3 (47.620)	Unnamed creek, open flats	Grazing land	60 m x 3.6 m ground clearance dual carriageways with opening between bridges. Exclusion fencing adjoining. Corresponds with T5 construction monitoring site. Monitoring commenced end of 2nd Quarter 2020 (26.05) two cameras.	Yes	Yes	4 (F1-F4)
G	Bridge A14	S3 (47.841)	Unnamed creek	Riparian forest	72 m x 3.6 m ground clearance dual carriageways with opening between bridges. Exclusion fencing adjoining. Corresponds with T6 construction monitoring site. Monitoring commenced end of 2nd Quarter 2020 (26.05) two cameras.	Yes	Yes	4 (G1-G4)

Site ref No.	Design ref	Project section (Chainage)	Waterway	Landscape/ Habitat type	Bridge / site specifications and monitoring details	Design raised for emu passage	Emu food plants used in landscaping^	No. cameras (camera id)
H	Bridge A16*	S3 (49.228)	None, floodplain	Grazing land on west, forest on east	80 m x 3.6 m ground clearance dual carriageways with opening between bridges. Exclusion fencing adjoining, and hybrid emu fence parallel with north bound carriage. Corresponds with T9 construction monitoring site. Monitoring commenced end of 2nd Quarter 2020 (26.05) four cameras.	Yes	Yes	4 (H1-H4)
I	Bridge A17	S3 (50.259)	Unnamed creek	Dry forest	45 m x 3.6 m ground clearance dual carriageways with opening between bridges. Exclusion fencing adjoining, and hybrid emu fence parallel with south bound carriage. Corresponds with T10 construction monitoring site. Monitoring commenced end of 2nd Quarter 2020 (26.05) two cameras.	Yes	Yes	2 (I1, I2)
J	Bridge A55*	S3 (51.2900)	None, floodplain	Grazing land on east, forest on west	62 m x 3.6 m ground clearance dual carriageways with opening between bridges. Exclusion fencing adjoining, and hybrid emu fence parallel with south bound carriage including emu gate. Monitoring commenced end of 3rd Quarter 2020 (25.08) one camera.	Yes	Yes	1 (J1)
K	Bridge A19*	S3 (52.423)	Chaffin Creek	Riparian and dry forest	78 m x 3.6 m ground clearance dual carriageways with opening between bridges. Exclusion fencing adjoining, and hybrid emu fence parallel with south bound carriage including emu gate. Monitoring commenced end of 3rd Quarter 2020 (25.08) one camera.	Yes	Yes	4 (K1-K4)
L	Bridge A50	S3 (53.758)	Unnamed creek	Dry forest	20 m, unknown ground clearance dual carriageways with opening between bridges. Monitoring commenced end of 2nd Quarter 2020 (26.05) one camera.	No	Yes	2 (L1, L2)
M	Bridge A20	S3 (54.696)	Unnamed creek	Dry forest	75 m x 3.6 m ground clearance dual carriageways with opening between bridges. Exclusion fencing adjoining. Monitoring commenced end of 3rd Quarter 2020 (25.08) two cameras.	Yes	Yes	4 (M1-M4)
N	Bridge A23*	S3 (57.015)	Champions Creek	Dry forest east, grazing land west	90 m x 3.6 m ground clearance dual carriageways with opening between bridges. Exclusion fencing adjoining and emu hybrid fence parallel with north bound carriage. Monitoring commenced end of 2nd Quarter 2020 (28.05) one camera.	Yes	Yes	4 (N1-N4)

Site ref No.	Design ref	Project section (Chainage)	Waterway	Landscape/ Habitat type	Bridge / site specifications and monitoring details	Design raised for emu passage	Emu food plants used in landscaping^	No. cameras (camera id)
O	Bridge A51	S3 (59.286)	Unnamed creek	Riparian forest	20 m, unknown ground clearance dual carriageways with opening between bridges. Exclusion fencing adjoining. Monitoring commenced end of 3rd Quarter 2020 (25.08) one camera.	No	Yes	2 (O1, O2)
P	Bridge A31	S4 (70.433)	Constructed drain / floodplain	Cropping land	29 m bridge over constructed drain, with 2.5 m between top of drain and bridge abutment. Opening between bridges. Monitoring commenced end of 3rd Quarter 2020 (25.08) one camera.	No	No	2 (P1, P2)
Q	Bridge A33	S4 (73.380)	Constructed drain / floodplain	Cropping land	35 m bridge x 2.9 height over constructed drain, with 2.5 m between top of drain and bridge abutment. Opening between bridges. Monitoring commenced end of 3rd Quarter 2020 (25.08) one camera.	No	No	2 (Q1, Q2)
R	Bridge A34	S4 (74.400)	Shark Creek / floodplain	Cropping land	448 m bridges x 3.6 m ground clearance with no opening between bridges and no exclusion fencing adjoining. Future monitoring proposed via searches for tracks and camera monitoring	Yes	No	1 (R1)

Monitoring of Emu usage at each potential crossing structure occurred continuously through the first year of operation (January-December 2021 for 365 days ~ 52 weeks). This involved the placement of camera traps (Stealth Cam GN45) below each structure, consisting of between 1-5 cameras depending on the width of the structure and conditions under the bridge (refer Table 2-4) and Plates 5 and 6. The number and configuration of cameras at each structure aimed to confirm Emu usage and determine the direction and frequency of Emu passes below the structure. Due the high risk of flooding, some cameras were positioned on the railing below the bridge soffit, pointing down to ground-level with the sensor set to 'extended' distance to ensure passing emus were captured (Plate 5). Cameras were also positioned on fauna furniture and trees close to the bridge, aimed at the spaces between the bridge pylons. The two combined camera positions were required for adequate spatial coverage below long bridges.

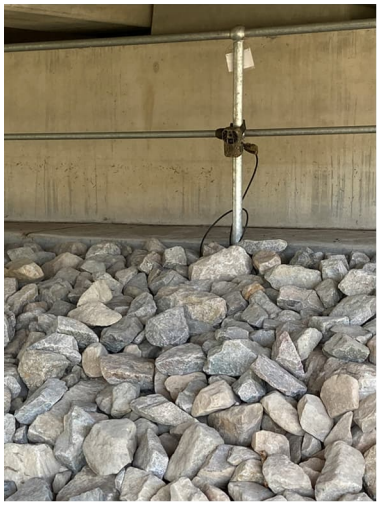


Plate 5. Example of camera traps positioned on railings and view of undercarriage

Plate 6. Example of fauna furniture used to attach multiple cameras across width of bridge opening

The cameras were set for continuous operation in daylight hours between 0500 and 2000 hours (1800 during winter) and set to take a single still image with a trigger interval of 5 seconds in attempt to capture direction of travel and pairs or groups of Emus or confirm juveniles with adults. Cameras were operational for average of 90 days per quarter, and image downloads and battery refresh were conducted at the end of each quarter in the same week as the site occupation surveys. Stolen, flooded and damaged cameras were replaced at the end of the quarter when required.

A minor flood event occurred in mid-March 2021, around 2 weeks after the end of summer camera change and six cameras were flooded and did not record images in the March-June survey period. Access to the bridges did

not occur as planned for end of August 2021 due to covid regional lockdown and forced travel restrictions to the site. Therefore, all cameras remained in place for 180 days without battery change which impacted the functionality of seven cameras that were found to be inactive in the September to November quarter due to battery fatigue.

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

Table 2.5: Crossing structure camera monitoring effort during 2021 operational phase monitoring; op3 summer, op4 autumn, op5 winter, op6 spring; n.s = not set; B.F = battery fatigue due to no access in op5, FL = camera flooded, not replaced; STL = camera stolen after setting, not replaced

Site No.	Section / Chainage	Camera	Camera trap days					Active weeks	Notes
			op3	op4	op5	op6	total		
A	S3 (43.881)	A1	69	98	91	91	349	49.9	
		A2	69	98	91	91	349	49.9	
		A3	69	98	91	91	349	49.9	
		A4	69	98	2	0	169	24.1	camera failure and B.F op5&6
		A5	69	98	83	0	250	35.7	camera failure and B.F op6
						Mean	*293*	*41.9*	
B	S3 (46.325)	B1	57	99	91	91	338	48.3	
		B2	69	70	91	91	321	45.9	
		B3	69	99	91	91	350	50.0	
		B4	69	98	91	91	349	49.9	
						Mean	*340*	*48.5*	
C	S3 (46.342)	C1	69	98	91	91	349	49.9	
		C2	70	30	91	91	282	40.3	
		C3	70	98	91	91	350	50.0	
		C4	69	98	91	91	349	49.9	
						Mean	*333*	*47.5*	
D	S3 (46.628)	D1	69	98	91	91	349	49.9	
		D2	69	98	91	91	349	49.9	
						Mean	*349*	*49.9*	
E	S3 (47.190)	E1	70	98	91	91	350	50.0	
		E2	70	1	35	0	106	15.1	camera failure in op4&5, BF op6
						Mean	*228*	*32.6*	
F	S3 (47.620)	F1	70	98	91	91	350	50.0	
		F2	70	98	91	91	350	50.0	
		F3	n.s	98	91	91	280	40.0	
		F4	n.s	98	91	91	280	40.0	
						mean	*315*	*45.0*	
G	S3 (47.841)	G1	54	98	41	91	284	40.6	BF end op5
		G2	70	98	91	91	350	50.0	
		G3	n.s	98	91	57	246	35.1	
		G4	n.s	98	91	91	280	40.0	
						mean	*290*	*41.4*	
H	S3 (49.228)	H1	70	98	91	91	350	50.0	
		H2	70	98	91	91	350	50.0	

		H3	70	98	91	91	350	50.0	
		H4	70	98	91	91	350	50.0	
						mean	*350*	*50.0*	
I	S3 (50.259)	I1	70	98	FL	n.s	168	24.0	flooded op5
		I2	70	1	FL	n.s	71	10.1	flooded op5
						mean	*120*	*17.1*	
J	S3 (51.2900)	J1	70	98	91	91	350	50	
						mean	*350*	*50.0*	
K	S3 (52.423)	K1	70	98	91	91	350	50.0	
		K2	70	98	91	91	350	50.0	
		K3	70	98	91	91	350	50.0	
		K4	70	98	91	91	350	50.0	
						mean	*350*	*50.0*	
L	S3 (53.758)	L1	70	98	91	91	350	50.0	
		L2	70	98	91	91	350	50.0	
						mean	*350*	*50.0*	
M	S3 (54.696)	M1	70	98	91	91	350	50.0	
		M2	70	98	91	91	350	50.0	
		M3	70	98	91	91	350	50.0	
		M4	70	98	91	91	350	50.0	
						mean	*350*	*50.0*	
N	S3 (57.015)	N1	70	35	STL	n.s	105	15.0	stolen op5, flooded op4,6
		N2	69	98	STL	n.s	167	23.9	stolen op5, flooded op7
		N3	70	2	91	91	254	36.3	flooded op4
		N4	70	24	91	91	276	39.4	flooded op4
						mean	*201*	*28.6*	
O	S3 (59.286)	O1	70	98	91	91	350	50.0	
		O2	70	98	91	91	350	50.0	
						mean	*350*	*50.0*	
P	S4 (70.433)	P1	70	98	91	91	350	50.0	
		P2	n.s	98	91	91	280	40.0	
						mean	*315*	*45.0*	
Q	S4 (73.380)	Q1	70	98	91	91	350	50.0	
		Q2	70	98	91	91	350	50.0	
						mean	*350*	*50.0*	
R	S4 (74.400)	R1	70	98	91	91	350	50.0	
						mean	*350*	*50.0*	

2.2.2 Fence and roadkill monitoring

During each quarterly camera inspection, exclusion and hybrid fences were walked north and south of the crossing structure to search for evidence of emu presence or passing through emu hybrid fences. Camera traps were also positioned facing the active emu gates. Care was taken to search for emu roadkill in the vicinity of the crossing structures, using vehicle searches, and during fence inspections. In addition, any reports of emu roadkill in the monitoring year have been collated and are discussed.

2.3 Emu sightings

A register of Emu sightings was maintained during construction by on-site personnel associated with the construction contractor. The register was maintained since the commencement of early works in Section 4 in mid-2016 and throughout the first three years of construction (2017-19). The register was an effective database for documenting sightings and observations of Emus within or adjacent to the construction corridor and had 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. The app was maintained through the remainder of the construction phase (2018-20). With the end of construction in mid-2020, no further dedicated register has been retained, although sightings of emus near the highway have been maintained by the author during monitoring periods and is reported to the author by Environmental Officers from Transport for NSW.

During the operational phase, sightings of Emus will be maintained largely through direct observations captured during monitoring activities, as well as observations provided by TfNSW staff while driving sections of the highway, and other observations provided by landowners accessed during monitoring. These opportunistic observations will continue to be reported.

2.4 Data analysis and limitations

2.4.1 Site occupation data

We correlated camera trapping rates of Emus with densities estimated from counts of signs made along the search transects. Two indexes of 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, camera trapping data and observed birds 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 and operational phases 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 'snagging' feathers from birds, and hence 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 as discussed previously.

2.4.2 Bridge camera data

Quarterly camera data from bridges were uploaded to a computer and viewed using Windows Photo Viewer. Data as recorded for site, active camera days, number of photos, presence of emus (date/time), number of individuals and direction travelled. Data on the presence and number of wild dogs/dingoes from the monitoring period was also gathered. As cameras are positioned centrally below the bridge, the presence of emus walking past the cameras was deemed to be a complete crossing of the highway.

The successful cameras days per monitoring period were pooled for all cameras at each site and then converted to active camera weeks for the monitoring year (year 1 operation) by dividing by seven. Presence of emus and use of the crossing zone was recorded as the number of emu detections per active week. This method for recording rate of use was considered suitable than absolute trap rates per total images captured, due to the high number of photographs of cattle and maintenance workers captured below each bridge.

2.4.3 Limitations

The site occupation surveys are influenced by changes to fenced transects, whereby some fences have been replaced with new 4 and 5 strand fencing during operation that was different to the pre-construction and construction surveys and possibly less penetrable by emus than the older fence type. Where this has occurred, the density of emu sign may be affected, and additional cameras have been used to address the limitation. Transects were not able to be accessed in the August survey due to covid travel restrictions and this impacted on camera batter fatigue on some transects.

The bridge monitoring program has been influenced by two large flooding events in early 2021, which saw four cameras inundated by flood waters. Two cameras were stolen from bridge N in mid-2021 and not replaced for the remainder of 2021, due to risk of further theft. Three cameras were not operational in the spring survey period (op6) as a result of access restrictions during covid lockdown and associated battery fatigue.

3. Results

3.1 Emu presence

3.1.1 Sign searches

Signs of Emu presence were recorded from each of the impact and control survey areas in at least one season during the first year of operation, with the exception of the Yuraygir south survey area (control). Emu sign was recorded in all three impact survey areas (Pillar Valley, Tucabia north and south) however all observations were east of the highway, and there was no evidence of emu presence west of the operational highway. As the transects were not able to be surveyed in August 2021, there is a gap in the data, which may have an impact on the mean scores, however subsequent monitoring events confirmed similarly low numbers and the sign data accounts for 5 operational monitoring events.

Emu sign was confirmed both east and west of the highway corridor during the construction monitoring period up until March 2019, however after this date there has been no emu sign recorded west of highway (Section 3) in the last 15 months of construction ending in June 2020 and in the first 18 months of operation to December 2021. Although Emus have been observed in cane fields both east and west side of the highway in Section 4 during this period.

The density of Emu sign during the first year of operation is significantly lower than from the two southern 'impact' survey areas compared with the 3-year pre-construction (baseline) period from the same locations (Pillar Valley west P=0.013; Tucabia south P=0.002) (Figure 3:). This pattern of decline was first observed during construction and there has been no change in Pillar Valley west and further decline noted in Tucabia south during this first 18 months of operation. The density of emu sign in the Tucabia north impact survey area has increased in the operational phase compared with baseline and construction but is not significant (P=0.696). This is an encouraging evidence of emu activity returning where absences were previously noted.

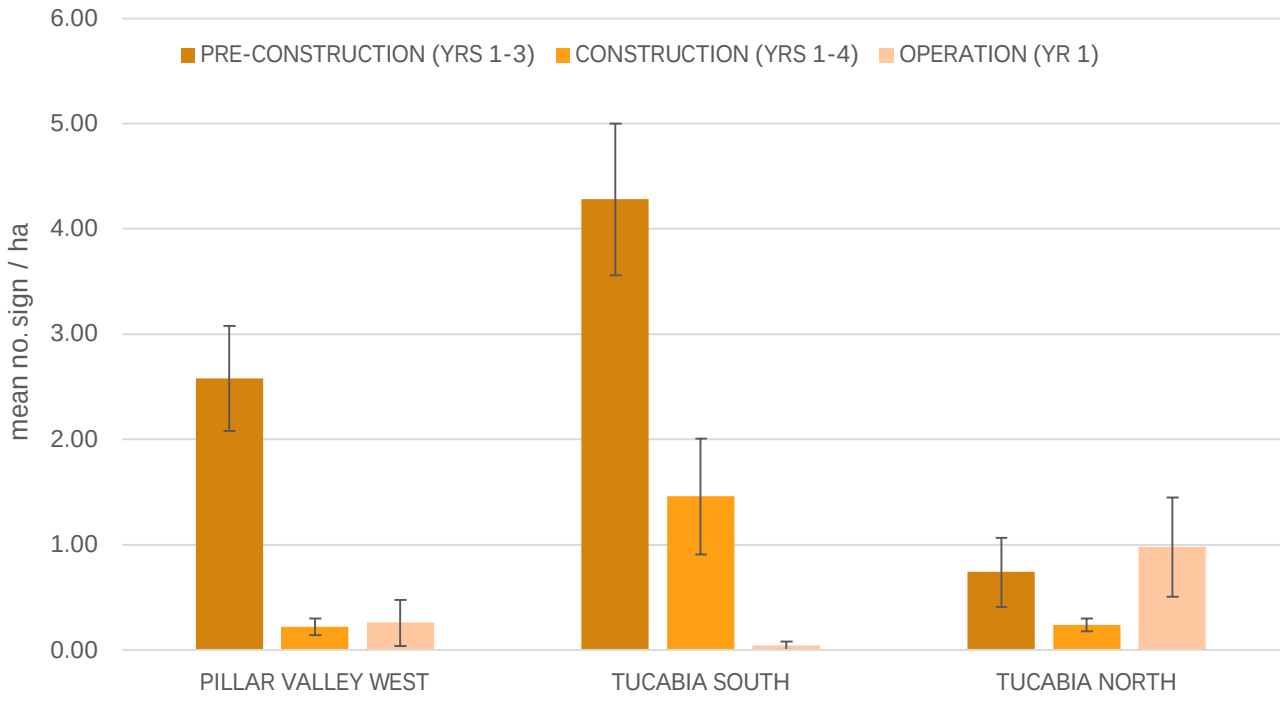


Figure 3: Mean density of Emu sign (no./ ha ±se) at impact survey areas comparing pre-construction (2014-16) and construction (2017-20), and operation (June 2020 to Dec 2021)

A similar pattern of continued temporal decline in the density of Emu sign from baseline through to operation is also evident at the 'control' survey areas, with a complete absence of Emu sign recorded in the Yuraygir south transects and a marked decline from the Yuraygir North transects during both construction and operational periods (Figure 4).

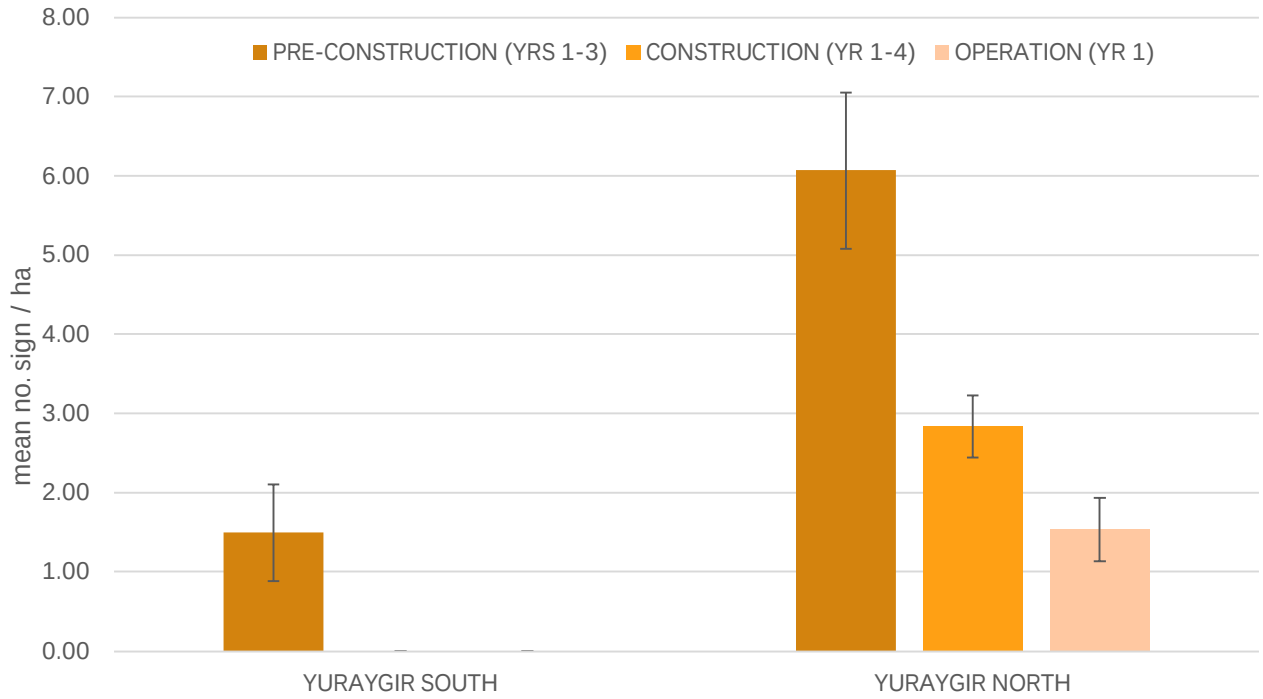


Figure 4: Mean density of Emu sign (no./ ha ±se) at control sites comparing pre-construction (2014-16) and construction (2017-20) and operation (June 2020 to Dec 2021)

Comparison of the change in density of emu sign data between baseline, construction and operation has been interpreted with consideration of the temporal patterns of Emu sign observed across the three impact study areas since 2014, three years prior to the commencement of construction. The density of Emu sign within each survey area has varied between season and years irrespective of construction Table (3.1). For example, pre-construction sign density was highest in 2014 before declining in 2015 and 2016 (prior to construction commencing in 2017). Monitoring during construction occurred in 2017-2020 and the general trend of declining Emu sign that was noted prior to construction commencing, continued during this phase. The commencement of operation has seen a promising increase in activity in Tucabia north, however this can be attributed to one transect located on the east of the highway and likely one or two animals. The lack of emu signs on the west of the highway during late construction and operation is contributing to the decline in activity data.

The density of Emu signs has also declined significantly in the Yuraygir (north and south) control survey areas since collation of baseline data in 2014. (Table 3.2). A significant difference between the pre-construction and construction years has been noted for the southern control area ($P = 0.01$) and northern control area ($P = 0.006$). The decline is also significant between pre-construction and operation periods in the southern control ($P = 0.01$), and northern control ($P = 0.01$). These data suggest either a decline in Emu numbers at the control sites or alternatively a shift away from these specific survey areas or transects to other proximal habitat areas within the range of the population. The data from the control areas suggest that Emu presence in localised areas can change over time, likely in response to changing environmental conditions and associated resource availability or behavioural traits, or morality of individuals occupying a specific area, this is also expected to be similar with impact areas.

Table 3.1: Density of Emu sign per ha recorded at the three impact study areas separated into years of pre-construction (2014-16 purple), construction (2017-20 green) and operation (June 2020-Dec21 orange)

Sampling period		Summer	Autumn	Winter	Spring	Summer	*Mean*	*SE*
Pillar Valley west	*2014*	2.56	3.68	3.52	6.40	5.60	*4.35*	*0.71*
	2015	2.56	0.80	2.24	1.92	0.96	*1.7*	*0.35*
	2016	0.64	1.44	1.28	-	-	*1.12*	*0.24*
	2017	0.32	0.96	0.32	0.16	-	*0.44*	*0.18*
	2018	0.48	0.48	0.00	0.00	-	*0.24*	*0.14*
	2019	0.32	0.00	0.00	0.00	-	*0.08*	*0.08*
	2020	0.00	0.00	-	-	-	*0.00*	*0.00*
	2020	-	-	0.00	0.00	-	*0.00*	*0.00*
	2021	0.00	0.16	-	1.12	-	*0.11*	*0.35*
Tucabia south	*2014*	6.52	9.78	5.87	1.74	1.96	*5.17*	*1.51*
	2015	7.61	5.87	3.26	3.48	2.61	*4.57*	*0.94*
	2016	3.26	1.52	2.17	-	-	*2.32*	*0.51*
	2017	6.52	4.78	3.48	1.30	-	*4.02*	*1.1*
	2018	1.09	0.43	1.74	0.87	-	*1.03*	*0.27*
	2019	0.22	0.00	0.00	0.00	-	*0.06*	*0.06*
	2020	0.00	0.00	-	-	-	*0.00*	*0.00*
	2020	-	-	0.00	0.00	-	*0.00*	*0.00*
	2021	0.00	0.22	0.00	0.00	-	*0.05*	*0.05*
Tucabia north	*2014*	0.00	0.00	3.22	1.52	3.22	*1.59*	*0.72*
	2015	0.95	0.19	0.00	0.19	0.00	*0.27*	*0.18*
	2016	0.19	0.19	0.00	-	-	*0.13*	*0.06*
	2017	0.57	0.57	0.19	0.57	-	*0.48*	*0.10*
	2018	0.19	0.38	0.00	0.38	-	*0.24*	*0.09*
	2019	0.00	0.00	0.19	0.38	-	*0.14*	*0.09*
	2020	0.00	0.00	-	-	-	*0.00*	*0.00*
	2020	-	-	0.00	2.46	-	*1.23*	*1.23*
	2021	1.70	0.38	0.00	0.38	-	*0.62*	*0.37*

Table 3.2: Density of Emu sign per ha recorded at the two control study areas separated into years of pre-construction (2014-16 purple), construction (2017-20 green) and operation (June 2020-Dec21 orange)

Sampling period		Summer	Autumn	Winter	Spring	Summer	*Mean*	*SE*
Yuraygir south	*2014*	5.53	4.42	3.87	4.61	0.92	*3.87*	*0.78*
	2015	0.18	0.00	0.00	0.00	0.00	*0.04*	*0.04*
	2016	0.00	0.00	0.00	-	-	*0.00*	*0.00*
	2017	0.00	0.00	0.00	0.00	-	*0.00*	*0.00*
	2018	0.00	0.00	0.00	0.00	-	*0.00*	*0.00*
	2019	0.00	0.00	0.00	0.00	-	*0.00*	*0.00*
	2020	0.00	0.00	-	-	-	*0.00*	*0.00*
	2020	-	-	0.00	0.00	-	*0.00*	*0.00*
	2021	0.00	0.00	0.00	0.00	-	*0.00*	*0.00*
Yuraygir north	*2014*	1.28	5.13	4.81	11.54	14.74	*7.50*	*2.45*
	2015	7.37	4.81	3.85	5.77	4.81	*5.32*	*0.60*
	2016	2.88	5.13	6.73	-	-	*4.91*	*1.12*
	2017	5.77	4.49	2.88	4.17	-	*4.33*	*0.59*
	2018	1.28	1.60	3.53	1.92	-	*3.21*	*0.50*
	2019	1.92	2.24	1.92	1.60	-	*2.78*	*0.13*
	2020	1.68	4.81	-	-	-	*3.25*	*1.57*
	2020	-	-	1.92	1.28	-	*1.60*	*0.32*
	2021	0.64	2.88	0.00	0.96	-	*1.12*	*0.62*

3.1.2 Camera trapping

During the year one operational monitoring Emus have been photographed at 5 of the 20 transects surveyed (25 %). This is compared with 61.1 %, 40 % and 30 % recorded during the 3-year pre-construction monitoring period. Mean camera trap rates in impact and control areas are shown in Figure 5, these show comparison of pre-construction data (2014-2016) with construction (2017-2020) and year one operation (June 2020-Dec 2021). Camera trap rates from the operational data in impact sites has declined from the baseline however this is not statistically significant (P = 0.093). While camera trap rates in control areas have increased during operation compared with lower construction sampling data but remain lower than the baseline at this early stage.

The decline in Emu trap rates between pre-construction with operation for the impact areas remains high at around 88 %, while the difference for control areas has reduced to only 12 % decline during operation. These are based on a lower operational sample size thus future monitoring will determine if rates are increasing back to baseline. These data are consistent with the trends observed from the Emu sign data. Emus were not photographed from impact transects during construction in 2019 or 2020, coinciding with the last 18 months of construction. However, an Emu was recorded in the Tucabia North impact transect in Pine Brush State Forest at the end of 2020, within the first 6 months of operation. Emus were also photographed at two bridge monitoring sites in Section 3 in 2021 (discussed in s.3.21) and both these bridges are in proximity to two of the transects with confirmed presence of emu signs during 2021.

The Yuraygir North control area recorded Emu photographs during each seasonal period in 2021, with the exception of spring, which is likely a factor of the reduced camera days due to being unable to change batteries at the end of the winter period as discussed in the methods. Importantly, an Emu was photographed from the Yuraygir South control area in November 2021, which follows other evidence reported in this location in October 2020.

No evidence of breeding (chicks or juveniles) was captured on camera traps at the impact or control study areas during the first year of operation.

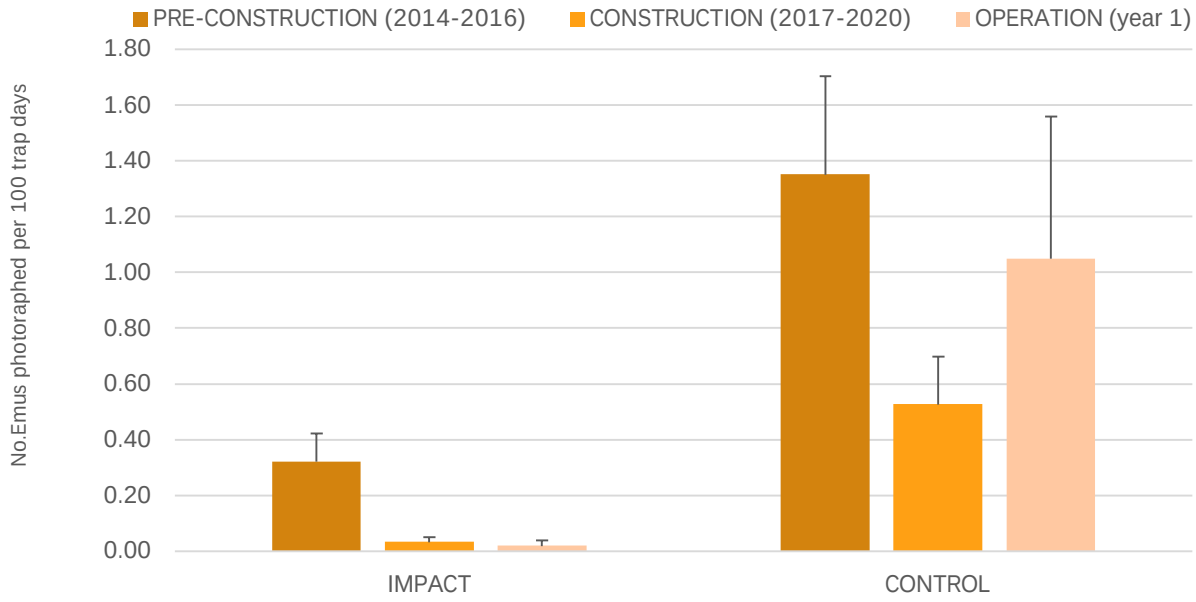


Figure 5: Mean camera trap rates (no. Emus photographed per 100 trap days ±se) at impact and control study areas for pre-construction period (2014-16), construction period (2017-20) and operation (Jun 2020-Dec 2021)

The camera trapping data is consistent with the temporal declines noted in the sign density discussed previously. These data are presented in Table 3.3 and show that a decline in trap rates in the impact areas of between 36 – 80 % had occurred in the pre-construction years (baseline) indicating that the declines in activity around the Section 3 impact area were occurring prior to any project construction related activity.

A one-way ANOVA (test of variance) was performed on the annual camera trap rates at each impact site comparing the pre-construction years (before) with the operational data (after). There have been declines in all three impact areas, which are not statistically significant. However, as the sample size is low at the site level, further analysis of the combined dataset for all impact areas (3 years baseline and 1.5 years operation) shows camera trap rates have in fact declined significantly in the impact study areas (*P=0.028*), but not control areas (*P=0.725*).

Camera trap rates of wild dogs were also recorded to monitor temporal change in dog presence in Emu survey areas. Dogs were found to be present on all transects during all phases of the monitoring program, indicating dogs and Emus co-exist within impact and control areas. Interestingly, there has been a notable reduction in the presence of dogs during the construction and operation compared with the baseline data, however this has also been noted from controls areas and the factors relating to this are unknown.

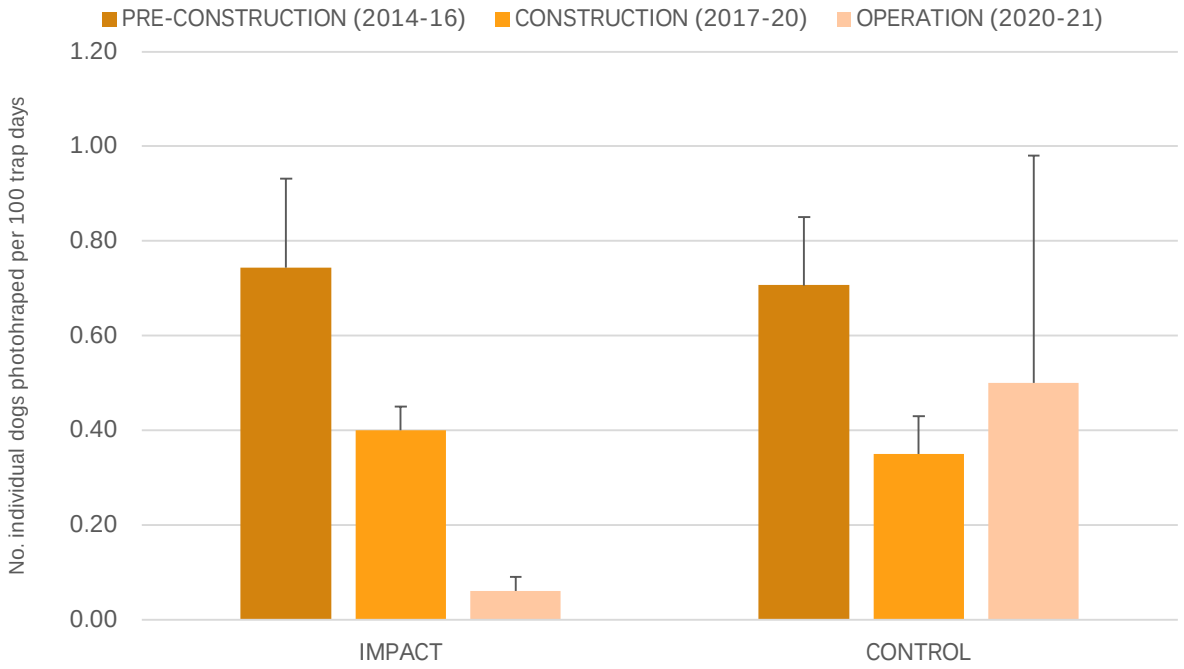


Figure 6: Mean camera trap rates (no. dogs photographed per 100 trap days ±se) at impact and control study areas for pre-construction (2014-16), construction (2017-June 20) and operation (June 2020- Dec21)

Table 3.3: Camera trap rate (no. Emu photos / 100 trap days) per study area recorded for pre-construction (2014-16), construction (2017-June 2020), and year 1 operation (June 2020-Dec 21)

Study area	Sampling year	Summer	Autumn	Winter	Spring	Summer	*Mean*	*SE*
Pillar Valley west (impact)	*2014*	0.00	0.92	1.16	0.13	-	*0.55*	*0.29*
	2015	0.00	0.00	0.00	0.99	0.00	*0.20*	*0.20*
	2016	0.19	0.00	0.17	-	-	*0.12*	*0.06*
	2017	0.00	0.00	0.00	0.00	-	*0.00*	*0.00*
	2018	0.00	0.00	0.00	0.00	-	*0.00*	*0.00*
	2019	0.00	0.00	0.00	-	-	*0.00*	*0.00*
	2020	0.00	0.00	-	-	-	*0.00*	*0.00*
	2020	-	-	0.00	0.00	-	*0.00*	*0.00*
	2021	0.00	0.00	0.00	0.00	-	*0.00*	*0.00*
Tucabia south (Impact)	*2014*	2.99	0.96	0.24	0.54	-	*1.18*	*0.62*
	2015	1.51	0.12	0.00	0.43	0.14	*0.44*	*0.34*
	2016	0.51	0.41	0.19	-	-	*0.37*	*0.08*
	2017	0.17	0.54	0.00	0.15	-	*0.22*	*0.11*
	2018	0.00	0.18	0.00	0.00	-	*0.05*	*0.05*
	2019	0.00	0.00	0.00	0.00	-	*0.00*	*0.00*
	2020	0.00	0.00	-	-	-	*0.00*	*0.00*
	2020	-	-	0.00	0.00	-	*0.00*	*0.00*
	2021	0.00	0.00	0.00	0.00	-	*0.00*	*0.00*
Tucabia north (impact)	*2014*	0.00	0.00	0.00	0.00	-	*0.00*	*0.00*
	2015	0.00	0.00	0.00	0.00	0.00	*0.00*	*0.00*
	2016	0.00	0.00	0.00	-	-	*0.00*	*0.00*
	2017	0.00	0.00	0.17	0.00	-	*0.04*	*0.04*
	2018	0.00	0.00	0.00	0.00	-	*0.00*	*0.00*
	2019	0.00	0.00	0.00	0.00	-	*0.00*	*0.00*
	2020	0.00	0.00	-	-	-	*0.00*	*0.00*
	2020	-	-	0.00	0.26	-	*0.13*	*0.09*
	2021	0.00	0.00	0.00	0.00	-	*0.00*	*0.00*
Yuraygir south (control)	*2014*	1.85	2.23	1.54	1.01	-	*1.66*	*0.26*
	2015	0.00	0.00	0.00	0.00	0.00	*0.00*	*0.00*
	2016	0.00	0.00	0.00	-	-	*0.00*	*0.00*
	2017	0.00	0.00	0.00	0.00	-	*0.00*	*0.00*
	2018	0.00	0.00	0.00	0.00	-	*0.00*	*0.00*
	2019	0.00	0.00	0.00	0.00	-	*0.00*	*0.00*
	2020	0.00	0.00	-	-	-	*0.00*	*0.00*
	2020	-	-	0.00	0.52	-	*0.26*	*0.26*
	2021	0.00	0.00	0.00	0.14	-	*0.03*	*0.03*
Yuraygir north (control)	*2014*	1.75	0.97	6.38	4.67	-	*3.44*	*1.26*
	2015	1.10	0.00	0.00	2.74	1.42	*1.05*	*0.51*
	2016	0.36	0.00	4.35	-	-	*1.57*	*1.39*
	2017	1.23	1.92	2.92	0.99	-	*1.77*	*0.43*
	2018	1.78	1.28	1.79	0.95	-	*1.45*	*0.20*
	2019	0.88	0.00	0.34	0.15	-	*0.34*	*0.19*
	2020	0.66	0.91	-	-	-	*0.79*	*0.13*
	2020	-	-	1.09	2.61	-	*1.85*	*0.76*
	2021	6.07	1.04	1.10	0.00	-	*2.05*	*1.36*

3.1.3 Site Occupation

Data from the sign survey and camera trapping for each period of monitoring were combined to identify the proportion of transects occupied by Emus within each survey period and each treatment (i.e., site occupation). As the home range and distance travelled by Coastal Emus is not well known, the data analysis has relied on the assumption that separate individuals or groups occupy the impact and control study areas. For example, it is feasible for the three impact survey areas that the same Emus could be detected on any of the thirteen transects sampled. Therefore, for the purpose of comparing site occupation rates, the impact site data was assessed as one whole survey area. 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 (Table 3.4). These variations are likely to reflect seasonal movements of Emus around the project area in response to the availability of food resources rather than impacts from construction. Emus were found to continually occupy the Yuraygir north transects (YNA and YNB) in all seasonal survey periods, and this may be related to the presence of reliable annual food resources.

Interestingly, the occupation data shows Emus returning to all three impact areas during early operation after long periods of absence during late construction, this was evident at Pillar Valley West (PVD) and Tucabia south (MRA) where Emus were reported 12 months after the start of operation after not being recorded in these impact areas for 2 years. Similarly, in Tucabia north there was a 12-month absence from near end of construction before birds had returned to these transect areas six months after operation. These data may reflect movements of Emus in response to the availability of resources and demonstrate that coastal Emus will return to locations previously reported at after long periods of absence, or that new individuals may move into suitable habitat that is not occupied. Figure 7 compares the mean occupation rate for each survey area (impact and control areas), comparing 12 pre-construction surveys (baseline) with 14 construction phase surveys and 6 operation phase surveys. The pre-construction and operation means were compared using an independent t-test with the dependent variable being occupation rate and the independent variable being time (pre-construction and operation). When comparing occupation ‘before’ construction with occupation ‘after’ construction, the proportion of impact sites occupied by Emus has declined significantly by 72.9 % (*P=0.00*), while the proportion of control sites occupied by Emus has also declined significantly by 28.3 % (*P=0.01*). Importantly, for the impact sites there was a notable decline in occupation rates during the pre-construction years of 47.4 % (prior to any disturbance). For the control sites there has also been a decrease in occupation rates during the pre-construction years (65.7 %).

These operational data only represent 6 surveys compared with 13 baseline surveys, and further monitoring is required. Additionally, the absence of Emu occupation in the winter of 2021 (see table 3.4) is a result of the covid lockdown as there was no access by the survey team. This does not reflect an absence of Emus during this period. Indeed, the occupancy rates during autumn and spring in year 1 operation were the highest in 2 years and the mean has increased to 13.5 % from the low rates at end of construction and end of the drought in 2019-20 (7.7 % and 1.9%).

Table 3.4: Site occupation rates (proportion of transects occupied) recorded seasonally at the impact and control study areas comparing pre-construction (2014-16 purple), construction (2017-June 20 green) and year one operation (June 2020-Dec 2021 orange)

Treatment	Sampling period	Summer	Autumn	Winter	Spring	*Mean*	*SE*
Impact	*2014*	85.60	90.00	90.90	92.30	*89.70*	*1.45*
	2015	84.60	46.20	38.50	69.20	*59.63*	*10.57*
	2016	30.80	46.20	46.20	46.20	*42.35*	*3.85*
	2017	61.50	53.80	61.50	46.20	*55.75*	*3.66*
	2018	46.20	38.50	7.70	23.10	*28.88*	*8.54*
	2019	23.10	0.00	7.70	0.00	*7.70*	*5.44*
	2020	0.00	0.00	0.00	7.69	*1.92*	*1.92*
	2021	7.69	23.08	0.00*	23.08	*13.46*	*5.77*
Control	*2014*	91.60	100.00	100.00	85.70	*94.33*	*3.49*
	2015	42.90	28.60	28.60	28.60	*32.18*	*3.58*
	2016	28.60	28.60	28.60	28.60	*28.60*	*0.00*
	2017	28.60	28.60	28.60	28.60	*28.60*	*0.00*
	2018	28.60	28.60	28.60	14.30	*25.03*	*3.57*
	2019	28.60	14.30	28.60	28.60	*25.03*	*3.58*
	2020	28.60	28.60	28.57	42.86	*32.16*	*3.57*
	2021	28.57	28.57	28.57	28.57	*28.57*	*0.00*

*No survey due to covid lockdown

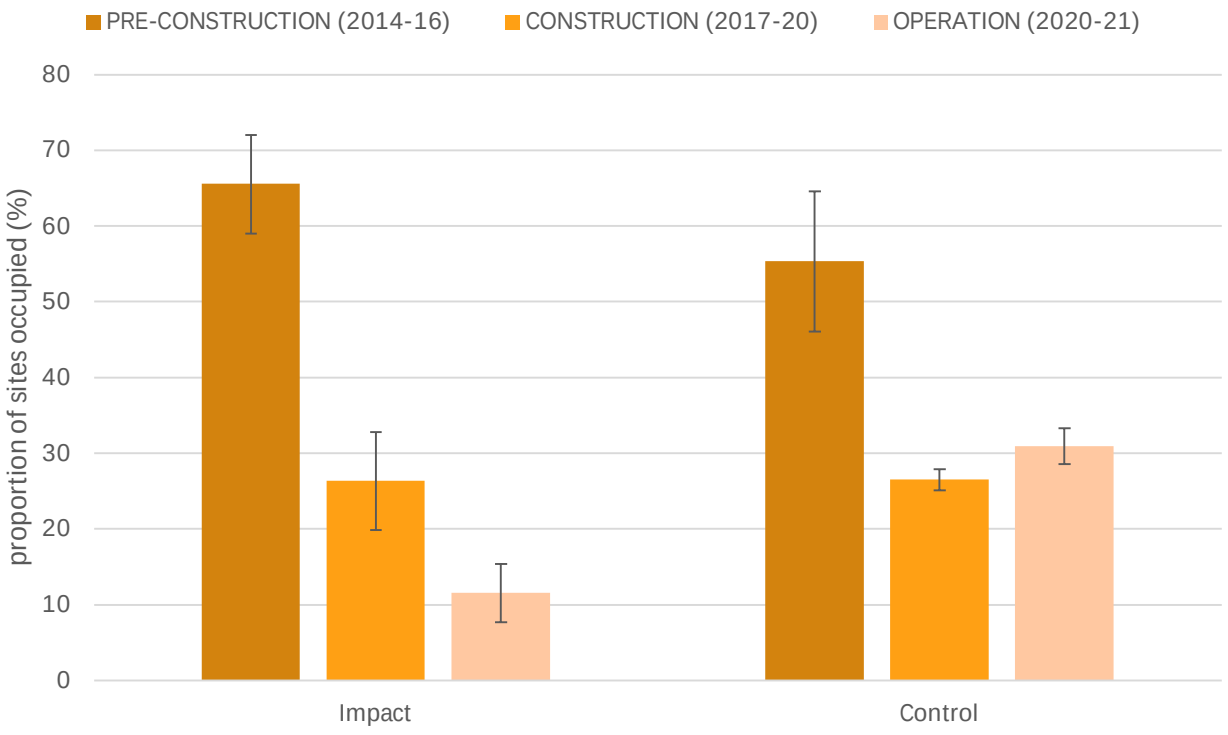


Figure 7: Mean site occupation rates (±se) for impact and control sites comparing pre-construction (2014-16), construction (2017-June 20) and year one operation (June 2020-Dec 2021)

3.2 Crossing structures

3.2.1 Emu detections

Monitoring Emu usage of crossing structures commenced from June 2020 as the highway became operational and continued through to the end of 2021. In total 51 cameras were deployed across 18 structures (15 bridges in Section 3 and 3 bridges in Section 4). Of these, 4 cameras were lost due to flooding in March 2021, two cameras were stolen in May 2021 and not replaced for remainder of 2021 and 3 cameras were not operational in the spring survey period (op6) as a result of access restrictions during covid lockdown and associated battery fatigue.

Emus were confirmed crossing the highway on 59 occasions from four separate bridges, this included 24 crosses in Section 3 (from two structures) and 35 crosses in Section 4 (from two structures) (refer Table 3.5). Three of the structures were raised bridges, with a minimum 3.6 metres ground clearance from below the bridge, and one structures over a cane drain in Section 4 is low, at only around 2.5 metres height from below bridge to ground level. The two bridges in Section 3 are divided carriageways, with space between the bridges, while the two bridges in Section 4 are a single span.

Emus were recorded traveling in both an easterly and westerly direction under all four structures. Observations in Section 3 were all of a juvenile bird, which is considered likely the same bird crossing both structure site E and F which are only c.400 metres apart. All observations were over a 68-day period in mid-winter to early spring (20 July to 26 Sept). Site E (chainage 47.190) is a 12-metre span, and this site was regularly used by emus during the pre-construction temporary fence trial and also was the only site of a confirmed emu crossing during the construction phase.

Observations in Section 4 were made of single and multiple adult birds, as well as juveniles, and adults with striped chicks. All observations were made over a 192-day period between early winter (14 May) to mid-spring (22 November). The results indicate that adult males are taking chicks and juveniles across the highway below the bridges and indicates learnt behaviour that is a positive for future generations of emus.

Both the crossing locations in section 3 were within grazing land with forest patches and occupied by cattle, and some images were taken of emus crossing the structure with cattle and indicating a learnt behaviour by the juvenile bird (see Plate 9).

Landscape plantings with known emu food plants were used at one of the four structures with confirmed crossing (25 %).

The two crossing locations in Section 4 were both in sugar cane cropping land and these two sites present higher usage rates then the grazing land, in particularly Site R (Shark Creek bridge) (Figure 8). Site P is a low bridge over a cane drain and only 2.5 metres clearance from the under surface to ground level, and as such traffic noise levels are high below the bridge and appear not to be a deterrent (see Plate 10).

Table 3.5: Details of camera trap images of emus crossing under the highway at four structures in Section 3 and Section 4 during the first year of operation

Section	Monitoring structure (*raised) (^landscape plantings)	Camera detections of emus	Mean no. weeks cameras active	Mean emu crossing detections per active week
Section 3	A *^	0	41.9	0
	B *^	0	48.5	0
	C *^	0	47.5	0
	D *^	0	49.9	0
	E *	6	32.6	0.18
	F *^	18	45.0	0.40
	G *^	0	41.4	0
	H *^	0	50.0	0
	I *^	0	17.1	0
	J *^	0	50.0	0
	K *^	0	50.0	0
	L ^	0	50.0	0
	M *^	0	50.0	0
	N *^	0	28.6	0
	O ^	0	50.0	0
	total	*24*	*652.5*	*0.04 (mean section 3)*
				0.03 (se)
Section 4	P ^	4	45.0	0.09
	Q ^	0	50.0	0
	R*	31	50.0	0.62
	total	*35*	*145.0*	*0.24 (mean section 4)*
				0.19 (se)

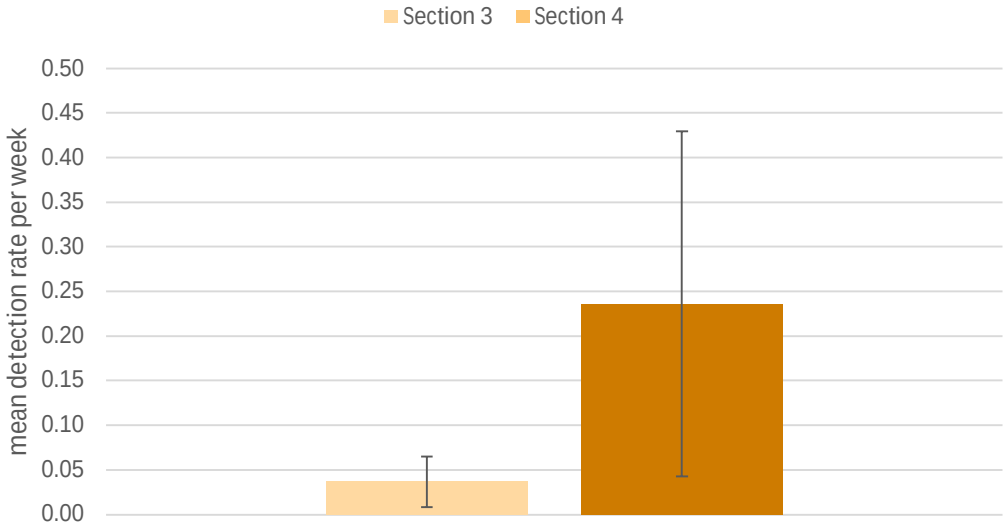


Figure 8: Mean detection rates / per week (±se) for emus photographed using bridges to cross highway in year 1 operation in section 3 and 4

Plate 7. Site P (cane drain Section 4) – adult and juvenile birds in autumn season 2021

Plate 8. Site F (bridge Section 3), repeat crossing by same juvenile during winter and spring 2021

Plate 9. Site F (bridge Section 3), juvenile Emu crossing below highway with cattle

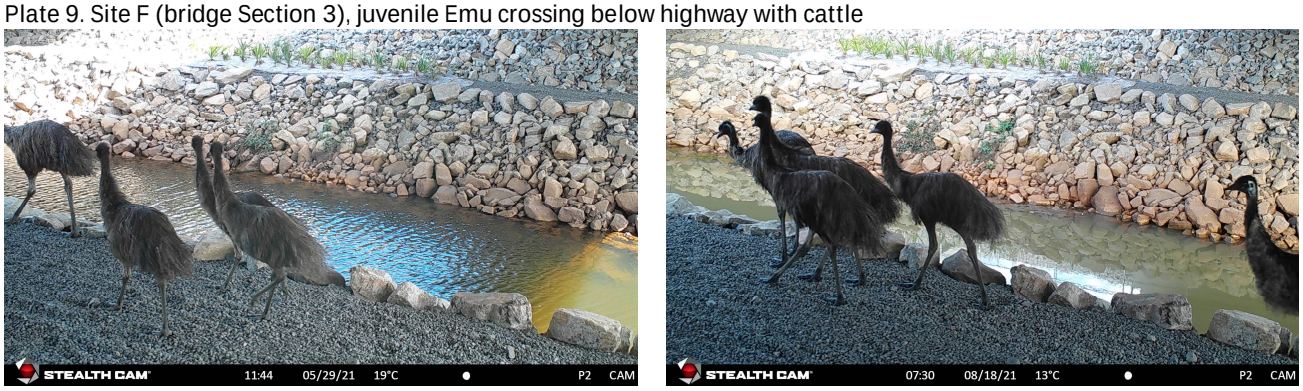


Plate 10. Site P (cane drain Section 4), adult male and 4 juveniles' late winter and spring 2021

Plate 11. Shark Creek Bridge (Section 4) adult male and striped chicks spring 2021

Plate 12. Shark Creek Bridge (Section 4) adult male and older sub-adults spring 2021

3.2.2 Fence and roadkill monitoring

An Emu was struck by a vehicle on the highway on 29 March 2021, on the southbound lane (approx. chainage 76.000), which is on a hill located between the McIntyres Lane overpass and Shark Creek bridge. The injured bird was collected and taken to local vet and euthanised. The incident was reported to TfNSW and immediately followed up with an inspection of the fauna fence between Shark Creek Road and McIntyre's Lane (east and west) to search for damage to the fence. The inspection identified a section of fauna fence where the top wire was broken at Chainage 75.800 (Plate14) and causing sagging of the wire across 10 metres of fence. The fence was subsequently repaired while staff remained at the site to prevent further crossing attempts by Emus. During the inspection, TfNSW staff in attendance had noted another adult emu with 3 juveniles walking the fence and looking for crossing opportunities (Plate 16).

Plate 13. Photo looking from hill to the south over the inundation on the floodplain

Plate 14. Damaged fauna fence idenified on western side of hill on 29.03.21, was repaired same day

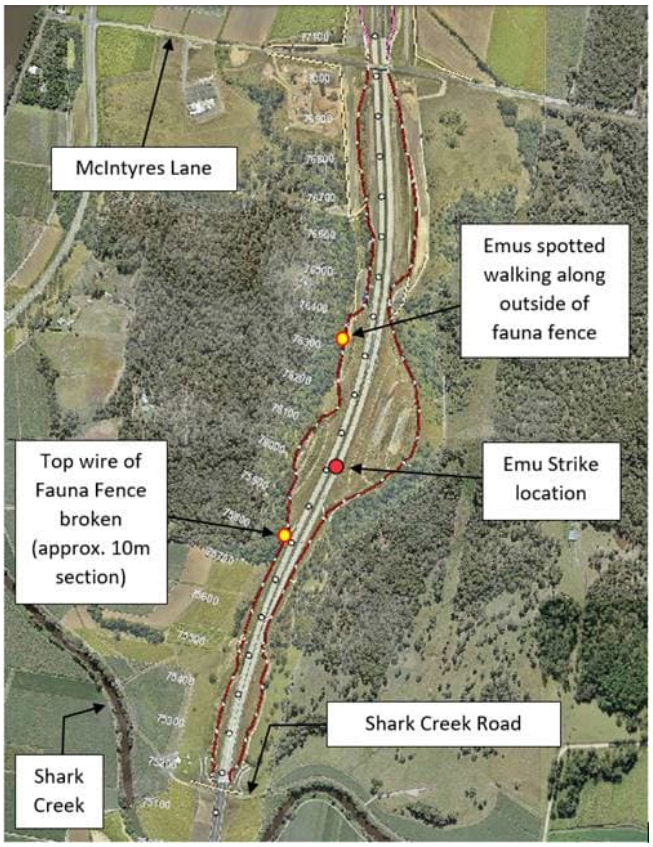


Plate 15. Map showing emu strike location and damaged fence on hill side north of the Shark Creek floodplain

Plate 16. Emus observed walking along the western fauna fence within vicinity of vehicle strike incident

This section of highway is on elevated land north of the floodplain referred to as Greenhills (Plate 15). The likely factor contributing to the incident, is directly related to significant rainfall which had fallen over the Shark Creek catchment in the weeks prior, both in February (289 mm) and March (397 mm). This had resulted in extensive flooding and restricting access for emus below the Shark Creek bridge (Plate 13). The area adjoining the bridge has been identified as a concentrated area for emu foraging and movements in the operational phase of the project (refer s3.2.1). Emus may have been temporarily stranded west of the highway and looking for opportunities to cross on the elevated section.

3.2.3 Dog detections

Dogs were infrequently recorded using the crossing zones, with one individual recorded in structure A (chainage 43.881 section 3) in summer and 3 dogs recorded at structure J (chainage 51.2900 Section 3) also in summer. A group of 5 dogs was also seen at structure A in November 2021. Despite the presence of dogs at two structures, there were no reported evidence of a dog attack on an emu, however emus have not been recorded using structure A or J at this stage

3.3 Emu sightings during operational phase

During the operational phase, sightings of Emus are being maintained through direct observations captured during monitoring activities, as well as observations provided by TfNSW staff while driving sections of the highway, and other observations provided by landowners accessed during monitoring. These opportunistic observations are noted in Table 3.6, and do not represent all occurrences of Emus near the project but are important as they note successful breeding and confirm locations relative to east and west of the highway.

Table 3.6: Opportunistic Emu observations made during operation of the highway in (June 2020 to December 2021), AD = Adult, SA = sub-adult, CH – striped chicks, Sect = project section

Date	AD	SA	CH	Sect	Easting	Northing	Location / observation
15/06/2020	1			3	510990	6708246	Pillar Valley Creek
30/07/2020	1			4	519261	6734021	east of highway in paddock south side of shark creek
27/08/2020	2			4	518795	6732823	edge of cane drain on west side Shark Creek bridge
13/09/2020	1		5	-	522280	6723697	Candole State Forest, north end near NP boundary
14/10/2020	1			-	525573	6731484	Taloumbi cane paddock
10/11/2020	2			4	518925	6733974	west of highway in paddock south side of shark creek
10/11/2020	1			4	519318	6734075	east of highway in paddock south side of shark creek
29/11/2020	1			4	519386	6733578	300 metres east of highway, south of shark creek bridge
10/12/2020	1			4	519363	6733517	300 metres east of highway, south of shark creek bridge
19/12/2020	2				525509	6731558	opposite wallaby lane in cane paddock
11/01/2021	1		3	3	513902	6717669	Bostock Rd, near dam, 300 m east of highway
26/01/2021	1			3	511339	6710279	Black Snake Creek
18/02/2021	1	9		-	527054	6733705	Taloumbi - edge of cane 600 m west of NP boundary
15/03/2021	1	5		4	520023	6737262	east of highway between Sheehan's Lane and Causley's Lane
29/03/2021	1			4	519581	6736158	walking along outside of fauna fence Ch 76300 west side of highway south of McIntyres lane
12/05/2021	1			4	515791	6731157	emu in the alignment Ch 69200, entered at the Tyndale interchange, was moved off site through gate
12/05/2021	1			-	521662	6703440	Minnie Water, east of Matenga Creek near NP boundary
18/05/2021	4			4	519016	6734149	west of highway in paddock south side of shark creek
25/05/2021	1	5		-	527903	6731251	Taloumbi - edge of cane 600 m west of NP boundary
25/05/2021	1			3	511920	6709551	Tucabia sth 500 m east of the highway
26/05/2021	1			3	515781	6718058	pine brush SF on transect TNB
27/05/2021	1				525407	6731623	opposite wallaby lane in cane paddock
21/06/2021	1	3		4	518758	6733994	west of highway in paddock south side of shark creek
21/06/2021	1			4	518931	6734050	West of highway and south of Shark Creek
20/10/2021	1			3	511336	6710275	10 m from road edge behind fauna fence, 100 m sth of Black Snake Creek
23/10/2021	3			4	519015	6734212	West of highway, Shark Creek
23/10/2021	1			4	519247	6733889	East of highway, Shark Creek
24/10/2021	2			4	517246	6731203	East of highway, Byron Lane
23/11/2021	1			3	511028	6709055	Feather on barbed fence
23/11/2021	1			3	514624	6715566	Feather on barbed fence
23/11/2021	1	3		4	519366	6733787	East of highway, sth of Shark Creek
23/11/2021	2			4	516096	6731105	East of highway, nth of southbound off ramp
23/11/2021	1				525387	6731658	Opposite Wallaby Lane Taloumbi, in cane paddock
5/12/2021	1			3	511503	6710915	West side of highway near bridge A13
8/12/2021	2			4	518937	6733802	West side of highway Shark Creek

4. Discussion

The mitigation goals outlined in the Emu Management Plan for the W2B project include:

- Zero rate of traffic related emu mortality in Sections 3 and 4 of the project after 10 years.
- Post-mitigation relative density in the Project study area is similar to pre-road construction relative density after 5 years.
- Post-mitigation distribution on both sides of the road is similar to pre-road construction distribution.
- Zero or reduced rate of emu deaths from dog attacks in vicinity of crossing structures in Section 3 and 4 of the project in years 1-5.

Specific mitigation measures were designed to achieve these goals and the monitoring program aims to determine the performance of these measures by monitoring and evaluating:

- Emu activity and distribution near the road corridor including east and west of the highway to determine if the road is creating a barrier to movements
- The trend in emu occupation in the project area and comparing this with control areas to identify if declines are related to the project
- The effectiveness of crossing structures, exclusion fences and revegetation.

The outcomes of the monitoring for the end of the first year of highway operation are discussed below.

4.1 Emu activity and site occupation

Emu activity and site occupation during year one operation have continued to be significantly lower than the pre-construction period in both the impact and control areas, reflective of a decline in the population during this period. This is likely to be independent of the project as baseline monitoring first detected a substantial decline in Emu activity and occupation rates over the 3-year pre-construction period, which continued during the construction phase. The decline has also continued in year one operation in the impact areas compared with the construction phase, while the control areas have maintained comparable activity levels for construction and operation, albeit increasing slightly during operation, but not significantly.

Operational monitoring is still in an early phase and the low sample size constrains the results somewhat when comparing with pre-construction, particularly given the gap in 2021 data that was due to covid travel restrictions. Importantly, the early occupation data shows a trend in Emus returning to all three impact areas after long periods of absence recorded during the construction phase. This was evident at Pillar Valley west and Tucabia south where Emu presence was confirmed in year one operation after an absence in these impact areas for the previous 2 years during construction. Similarly, in Tucabia north there was a 12-month absence from near the end of construction before a return to these sites 6-months after start of operation.

The absence of emus in the project area during the final two years of construction coincides with a period of below average rainfall and drought conditions in the project areas during 2018-2019. Emus are known to be semi-nomadic, keeping in touch with variation in availability of food which is triggered by rainfall (Davies 1976; 1984) and availability of drinking water (Dawson et al 1983). Since the start of the operation phase, from late 2020 to 2021, above average rainfall in the W2B project area has resulted in substantial amounts of water returning to local creeks and floodplain areas and would likely account for the return of Emus to the Pillar Valley and Tucabia impact areas in proximity to the highway. These data also demonstrate that coastal Emus will return to locations after long periods of absence, or that new individuals may move into favourable habitat that is not occupied, and a temporary absence is likely related to a change in resources or environmental variables.

All records of Emus reported from the transect monitoring during year one operation have been reported on the eastern side of the highway. While transect monitoring confirmed Emus both east and west of the highway during the pre-construction phase and early construction monitoring period up until March 2019. After this date,

there has been no evidence recorded west of highway (in Section 3) in the last 15 months of construction ending in June 2020 and this trend has continued in the first 18 months of operation to December 2021 (almost 3 years). Although, there was a direct sighting of an Emu away from a transect in December 2021 on the west side of highway north of the Pillar Valley Creek floodplain (refer s3.3). This confirms presence of at least one bird on the west side of the highway in section 3 during year one operation. Emus have been observed regularly in cane fields both east and west side of the highway in Section 4 during year one operation, and there are no monitoring transects in Section 4.

In the cane properties surrounding section 4 of the project, Emu presence has been regularly reported near the highway during year one operation, as determined from direct observations made from the highway between the Tyndale interchange to Shark Creek. Emus were reported year-round with peaks in early autumn and spring accounting for periods of breeding and post-breeding. Groups of birds, chicks and sub-adults were all recorded indicating breeding success, and the importance of the cane properties in providing resources for breeding birds and juveniles. The higher presence of emus in Section 4 is reflected in the bridge monitoring data.

4.1.1 Performance thresholds and corrective actions

The monitoring of emu presence has been designed to provide a baseline of emu presence and activity prior to construction, and then comparing this with operation to identify change. The monitoring program outlined in the Emu Management Plan (s.7.2.4) identifies two key performance thresholds in relation to emu activity and occupation that are to be measured, namely:

- 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 decline in Emu activity is measured using the site occupation data which compares the site occupation rate for each survey area (impact and control areas), comparing 12 pre-construction surveys (baseline) with 14 construction phase surveys and 6 operation phase surveys. When comparing occupation ‘before’ construction with occupation ‘after’ construction, the proportion of impact sites occupied by Emus has declined significantly by 72.9 %, while the proportion of control sites occupied by Emus has also declined significantly by 28.3 %. Importantly, for the impact sites there was a notable decline in occupation rates during the pre-construction years of 47.4 % (prior to any disturbance). For the control sites there was also a decrease in occupation rates during the pre-construction years (65.7 %). The difference between pre-construction and operation is 25.5% for the impact study areas and 27.4 % for control study areas and represents a greater than 15 % decline for both treatments, however a difference of only 2 % between treatments indicating a comparable decline has occurred between impact and control areas. The decline is considered independent of the project and as such there is no corrective action, and monitoring is to continue.

The direct observations made during year one operation have recorded evidence of breeding in both Section 3 and Section 4 as well as control areas. Groups of adult birds have been observed in the autumn breeding period and the presence of striped chicks, juveniles, sub-adults recorded in spring and summer in proximity to the project. The project is not expected to have impacted breeding success

4.2 Monitoring effectiveness of crossing structures

The year one operational monitoring confirmed usage of the bridge structures by Emus crossing the highway. Birds were detected on camera travelling in both an easterly and westerly direction below bridges at four locations, which included single and multiple birds, and adults with juveniles and very young striped chicks. Shark Creek Bridge (Section 4) in particular was identified as a regular crossing location for Emus foraging in the cane fields east and west of the highway and is consistent with the high number of direct observations made from the highway over this period.

There was considerable variation in the type and specifications of the structures used by Emus, with the cane drain in section 4 having only about 2.5 metre ground clearance and not designed specifically for emu passage, while Shark Creek bridge at around 3.6 metres ground clearance, and the two bridges in Section 3 also 3.6 metre ground clearance. All four bridges were located in an open agricultural landscape (two in cane land and two in grazing land) with a mosaic of large and small forest patches in the surrounding landscape. Artificial tracks were present at each site, and these are used by famers for vehicle access below bridges and driving cattle. Landscape plantings were used at one of the four sites.

Some additional observations from the year one operational structure monitoring include:

- the low height of the cane drain bridge demonstrates that traffic noise is not a deterrent in this location
- adult males were observed crossing with chicks and juveniles, and this can be interpreted as learnt behaviour for the next generation of birds
- An emu observed crossing below bridges with small groups of cattle, indicting the presence of cattle herds is not a deterrent and emus may have learnt to cross the highway by observing cattle
- Observed foraging on plants growing below bridges reinforces the mitigation approach to using landscape plantings to attract emus to a structure location

4.2.1 Performance thresholds and corrective actions

The project mitigation measures for connectivity have been designed to minimise the impacts of habitat loss and fragmentation on Coastal Emus and the potential barrier effect of the highway. The monitoring program outlined in the Emu Management Plan (s.7.3.2) identifies three key performance thresholds that are to be measured, namely:

- No evidence of east-west movements across the project corridor after 5 years post-construction
- Emus found on western side of the highway but no evidence of using crossing structure (i.e., isolation)
- A single dog or fox attack reported in proximity to a crossing structure or along an exclusion fence, through evidence of dogs and foxes reported on surveillance cameras and / or a dead emu found

The year one operational monitoring confirmed usage of the crossing structures by emus, and birds were detected on camera travelling in an easterly and westerly direction below bridges at four locations (2 in Section 3; and 2 in Section 4) indicating movements across the project corridor in the first year of operation. The emu sighting data shows emus regularly in cane fields on the east and west of the highway in Section 4. It is important to note the intent of the connectivity mitigation in Section 4 was not aimed at maintaining emu movements across the project, however this outcome is evident and should be considered in future discussion around crossing locations and habitat connectivity as it evident that the sugar cane farms provide important habitat. The usage of bridges is confirmed six times higher in Section 4 than section 3, despite the presence of four times as many structures in Section 3.

While a single individual emu has been reported using two structures in section 3, the transect data at this stage has not been conclusive in determining emu activity west of the highway in the impact areas. All records of emus reported in the emu activity monitoring have been on the east side of the highway. Further monitoring is required to determine east west movements and activity both sides of the highway in Section 3 which is the key area that connectivity mitigation measures were focused in the Coastal Emu Management Plan.

Dogs have been infrequently reported below bridge structures in year one operation and were reported at only two structures in section 3, neither of which have not been used by emus to date. There was no evidence of a dog attack on an emu associated with a crossing structure. A pack of 5 dogs was recorded at structure A (chainage 43.881) in November 2021 and further monitoring will continue at this site to include checks for dog attacks.

4.3 Exclusion fence monitoring

An Emu was struck by a vehicle on the highway on 29 March 2021, on the southbound lane (approx. chainage 76.000), which is on a hill located between the McIntyres Lane overpass and Shark Creek bridge. An inspection of the fauna fence in this location determined there was a break in the wire. Further to this an emu was also reported in the road corridor at Chainage 69.200 at the Tyndale Interchange in May 2021, which may have entered through a gap in the exclusion fence and was moved off site through a gate.

4.3.1 Performance thresholds and corrective actions

The project mitigation measures for exclusion fencing have been designed to minimise the impacts of vehicle strike on Coastal Emus. The Monitoring Program outlined in the Emu Management Plan (s.7.4.2) identifies five key performance thresholds that are to be measured, namely:

- Evidence of an emu injured by the exclusion fencing or hybrid fence
- Evidence of an emu breaching the exclusion fencing system and entering the roadway
- Evidence that the hybrid fence is ineffective through the camera monitoring program
- A single road fatality recorded on the highway in Section 3 and Section 4 of the project during10 years operation

There has been no evidence of an emu injured by exclusion fencing in year one operation. The reported emu road strike in March 2021 was immediately followed with a corrective action to survey and inspect the exclusion fence, and subsequent repairs were made to the fence within 24 hours of the incident being reported, which follows the corrective actions in the Emu Management Plan (Table 7.3). No further road fatalities were reported in year one operation.

Where there is evidence of an emu breaching the exclusion fencing and entering the roadway the corrective action is to survey the fence and make repairs. No reported survey, damage, or repair of the fauna fence at chainage 69200 at the Tyndale Interchange has been advised. It is important to complete this to assess if the fence is damaged, or if not, further consideration of the fence design or any perceived gaps, is appropriate in line with corrective action 3 in Table 7.3 of the Emu Management Plan.

Emus have been regularly reported in proximity to the road in Section 4 during year one operation, and exclusion fencing has been used in this location. The fact that two emus have been reported inside the fauna fence in Section 4 in only the first year of operation is of concern in considering the effectiveness of the exclusion fence at preventing future vehicle strike risk. As the Emu fatality was linked to inundation of the floodplain and inaccessibility under Shark Creek Bridge at the time (which a known crossing point) this further emphasises the importance of maintaining the integrity of fauna fencing in Section 4 to prevent future road strike by birds needing to cross while bridges under flood water.

There has been no evidence of hybrid fences or emu gates being used in year one operation.

5. Recommendations

This report is the first year of operational monitoring for Coastal Emu, and monitoring has indicated that performance thresholds for emu activity and occupation are being met, and that early trends for continued emu activity on the east and west of the highway are looking positive considering the confirmed usage of crossing structures in both Section 3 and Section 4. Further monitoring is required to determine activity levels west of the highway.

The road fatality at Greenhills and the damaged exclusion fence and the presence of an emu inside the fence at the Tyndale interchange are of concern for the life of the project. An inspection of the fence at the Tyndale Interchange should occur to determine if there is damage or a gap in the fence and subsequent repairs made. An annual inspection of the fence in Section 4 from Greenhill to Tyndale interchange should occur during the first 10 years of operation to ascertain whether the fence is maintaining its integrity or whether modification is required in order to meet this mitigation goal. This is important given the density of emu activity reported in section 4 and the known flooding of structures and like impact on fencing in this location, after high rainfall events. Additional inspections should occur after significant rainfall events which cause localised flooding.

Table 5.1: Recommendation following Year 1 operational monitoring and Transport for NSW response.

No.	Recommendation	Transport for NSW
1	Conduct an inspection of the exclusion fence in the vicinity of chainage 69.200 (Tyndale Interchange) near reported breach to assess damage and or gaps in fence and make repairs if necessary	TfNSW undertook an inspection of the exclusion fence following the emu entering the road corridor. No breach points were found. The only opening in the exclusion fence is for the connecting Big River Way and subsequent entry onto north bound on-ramp onto the Pacific Highway. It is possible that the emu has entered at this location by walking along the road. There is no option to fence across the road.
2	Conduct an annual inspection of the fauna exclusion fencing in Section 4 between Greenhill and Tyndale interchange during the first 10 years of operation to check for fence integrity and determine suitability of the design. Additional inspections are required after flood events.	TfNSW maintenance schedule includes annual inspections of fauna exclusion fencing to check fence integrity. The schedule also includes inspections following major flood events.
3	Continue to collate and report incidental sightings of emus to the author in Section 3 and 4, including breaches of the fauna exclusion fence and vehicle strike incidents	Adopted.

6. References

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Appendix A. Camera detections of emu crossing under bridges in year 1 operation

Site No.	Section / Chainage	Structure	Habitat	Date	Photo description	Direction travelled
E	(3) 47.190	Bridge 20 m x 3.6 m ground clearance dual carriageways with opening between bridges. Exclusion fencing adjoining	Grazing land, open flats and patches of swamp forest	25.07.21	Juv bird 12:01	East
				02.09.21	Juv bird 12.11 – 3 photos	Unknown
				08.09.21	Juv bird 09:08	West
				11.09.21	Juv bird 12:07 – 2 photos	West
				15.09.21	Juv bird 12:57	West
				20.09.21	Juv bird 10:10	West
F	(3) 47.620	Bridge: 60 m x 3.6 m ground clearance dual carriageways with opening between bridges. Exclusion fencing adjoining.	Grazing land, open flats with first order stream	20.07.21	juv bird 11:31 – 4 photos	East
				25.07.21	juv bird 16:49	East
				04.08.21	juv bird 10:57	West
				11.08.21	juv bird 13:53 – 2 photos	West
				13.08.21	juv bird with cattle 11:20	East
				17.08.21	juv bird 10:55 – 2 photos	West
				20.08.21	juv bird 10:52	East
				21.08.21	juv bird12.27 – 3 photos	West
				25.08.21	juv bird 09:06 with cattle	East
				25.08.21	juv bird 16:37	West
				28.08.21	juv bird 10.23	East
				30.08.21	juv bird 09:10	East
				01.09.21	juv bird 11:36	East
				06.09.21	juv bird 08:55	East
				16.09.21	juv bird 16:54	West
				18.09.21	juv bird browsing 08:06	East
				18.09.21	juv bird 12.10	West
				26.09.21	juv bird 16:10	west
P	(4) 70.433	29 m bridge over constructed drain, with 2.5 m between top of drain and bridge abutment. Opening between bridges.	Cropping land (sugar cane)	14.05.21	1 adult and two juveniles	East
				29.05.21	Adult male and 3 juvs 11:44	East
				15.07.21	1 adult bird and two juveniles	East
				18.08.21	2 adults and 3 juvs 07:30	East
R	(4) 74.400	Bridge 448 m x 3.6 m ground clearance with no opening between bridges and no exclusion fencing adjoining	Cropping land (sugar cane)	31.5.21	1 adult and 2 juv 13:09	West
				16.6.21	1 Adult, 3 juvs 11:32 - 5 photos	East
				30.6.21	1 Adult, 3 juvs 16:04 – 2 photos	West
				03.07.21	1 adult, 3 juvs 16:25	West
				27.7.21	1 adult 10:54 – 3 photos	West
				01.08.21	1 Adult 10:04 – 2 photos	East
				05.08.21	1 adult 09:42 – 2 photos	East
				15.08.21	1 adult 15:32 – 2 photos	East
				25.08.21	1 adult 12:35 – 2 photos	East
				16.09.21	1 adult 13:23 – 2 photos	East
				19.09.21	1 adult 12:52 – 3 photos	East
				25.09.21	2 adults 05:27	East
				27.09.21	3 adults 15:19 – 6 photos	East
				28.09.21	2 adults 09:39 grazing – 3 photos	East
				01.10.21	2 Adults, 1 sub-adult 06:53	East
				04.10.21	1 adult, 3 sub-adult 17:28 – 2 photos	West
				06.10.21	Adult+2 striped chicks 12:24 – 2 photos	West
				06.10.21	Adult 15:21 – 4 photos	West
				14.10.21	Adult 12:43 – 3 photos	West

				15.10.21	Adult 08:52	East
				15.10.21	2 Adults 15:13 – 3 photos	East
				16.10.21	Adult +4 sub-adults, grazing 17:10	West
				18.10.21	Adult 13:22 – 2 photos	East
				01.11.21	3 adults 11:05	East
				06.11.21	Adult+3 striped chicks 12:52 – 2 photos	East
				08.11.21	Sub-adult 17:44 – 2 photos	East
				09.11.21	Adult 10:08 – 3 photos	East
				10.11.21	Adult 10:19 – 2 photos	West
				19.11.21	Adult male+2 juvs	East
				21.11.21	Adult 06:39	West
				22.11.21	Adult 07:41	East