Woolgoolga to Ballina Pacific Highway upgrade

Coastal Emu Monitoring Program

Annual Report 2023

Operational Phase (Year 3/4)

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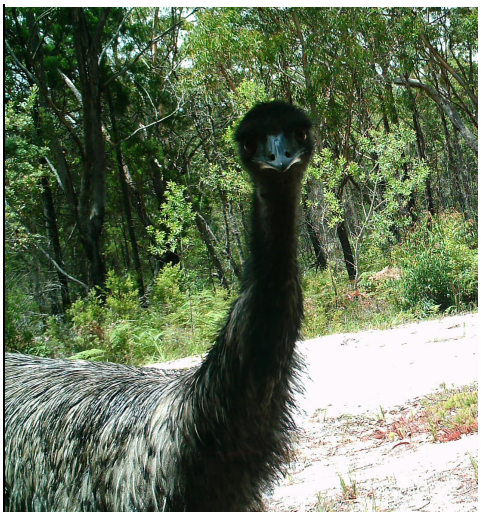
Woolgoolga to Ballina Pacific Highway Upgrade

Coastal Emu Monitoring Program – Annual Report 2023

Year 3/4 Operation

29 July 2024

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 a requirement to prepare and implement 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 2020 and operation of the highway in section 3 and 4 commenced in June 2020. This report outlines the methods and results of Emu monitoring (population and structure use) for the duration of 2023, which includes year 3 of the operational phase (Q1&2 2023) with the inclusion of data from two sampling periods (6 months) in the year 4 operational phase Q3&4 2023.

1.2 Overview of the monitoring program

The Coastal Emu 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 temporal presence/absence and site occupancy of emus within each of the survey areas across the different project phases (pre-construction, construction and operation). This is achieved by repeat sampling of between 2 and 5 transects in each survey area using transects that range between 800 and 2400 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 grazing 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 individuals are nomadic and occupy large areas, the absence of emu sign from a transect in any time period does not necessarily reflect the absence of emus in the study area, but rather a temporal 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 necessitated on occasion having to extend 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***		

JACOBS NSW SPATIAL - GIS MAP file : J:\IE\Projects\04_Eastern\IA136900\22 Spatial\Directory\Templates\Figures\IA136900_Emu_F002_Transects_r1v2.mxd | 4/08/2020

Legend

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

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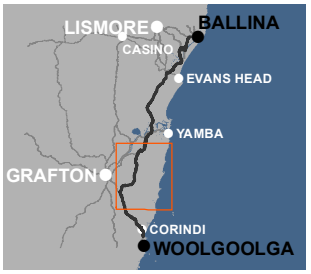
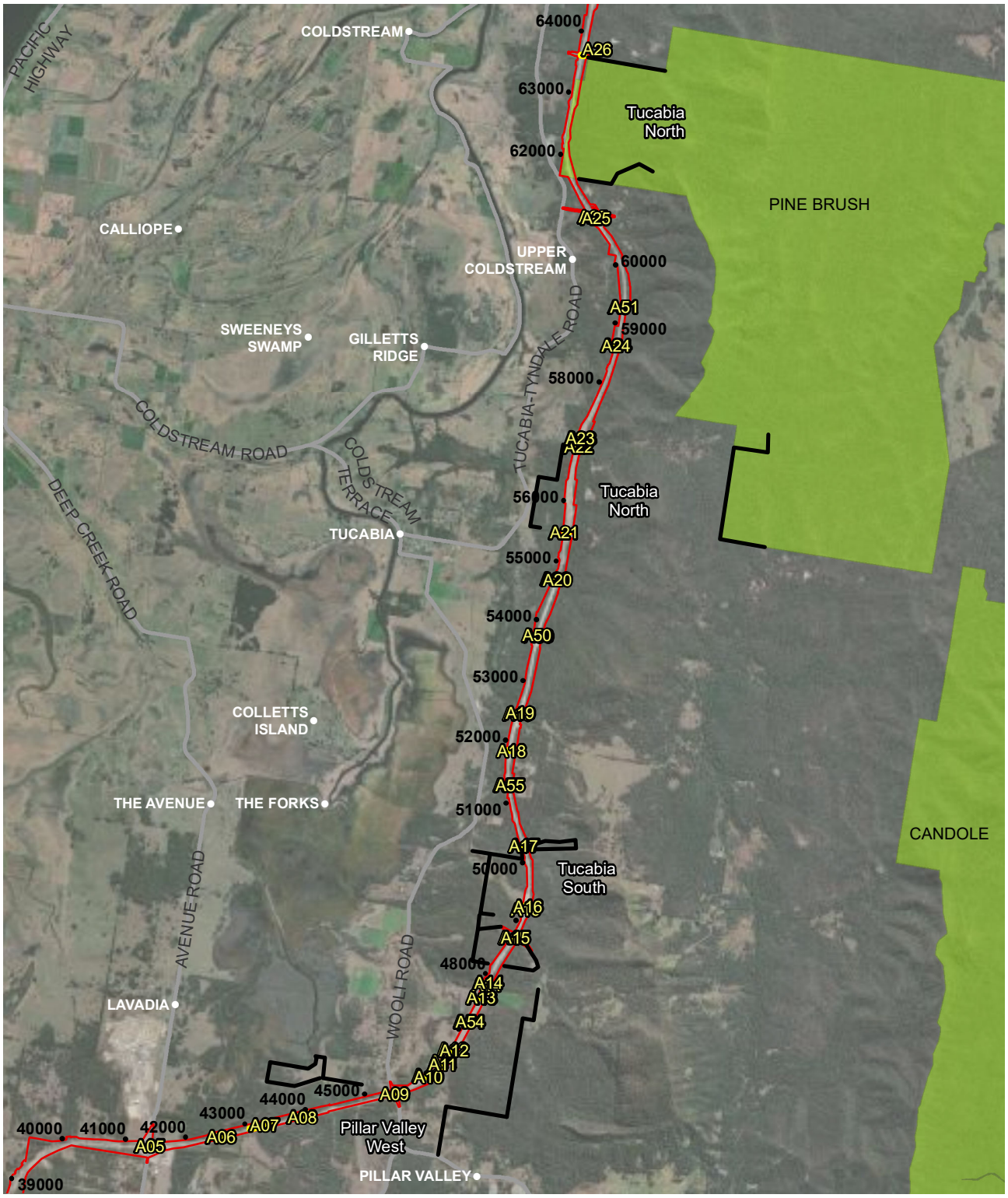


Data sources

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



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Legend

- Approved Project Boundary
- State Forest
- Impact transects
- Bridge sites

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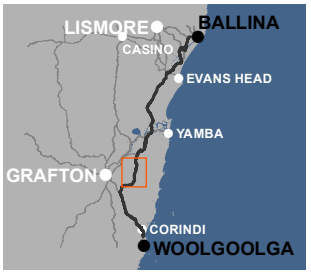


Data sources

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).

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 and Swift Enduro), 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 along the transect.

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

Table 2.2: Summary and comparison of camera trapping effort during each project phase 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 14 quarterly (seasonal) monitoring periods (op1-op14)	Camera monitoring days per season	91.5	91.5	91.5	91.5	91.5
	No. successful cameras	6.1	9.6	6.9	3.6	8.0
	Mean trapping days per camera	80.6	83.2	73.6	75.7	73.6
	Total camera trap effort (days)	***545.0***	***818.7***	***612.4***	***318.2***	***701.2***

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 Coastal Emu Management Plan, the monitoring program is to be designed to compare a range of crossing structure 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.

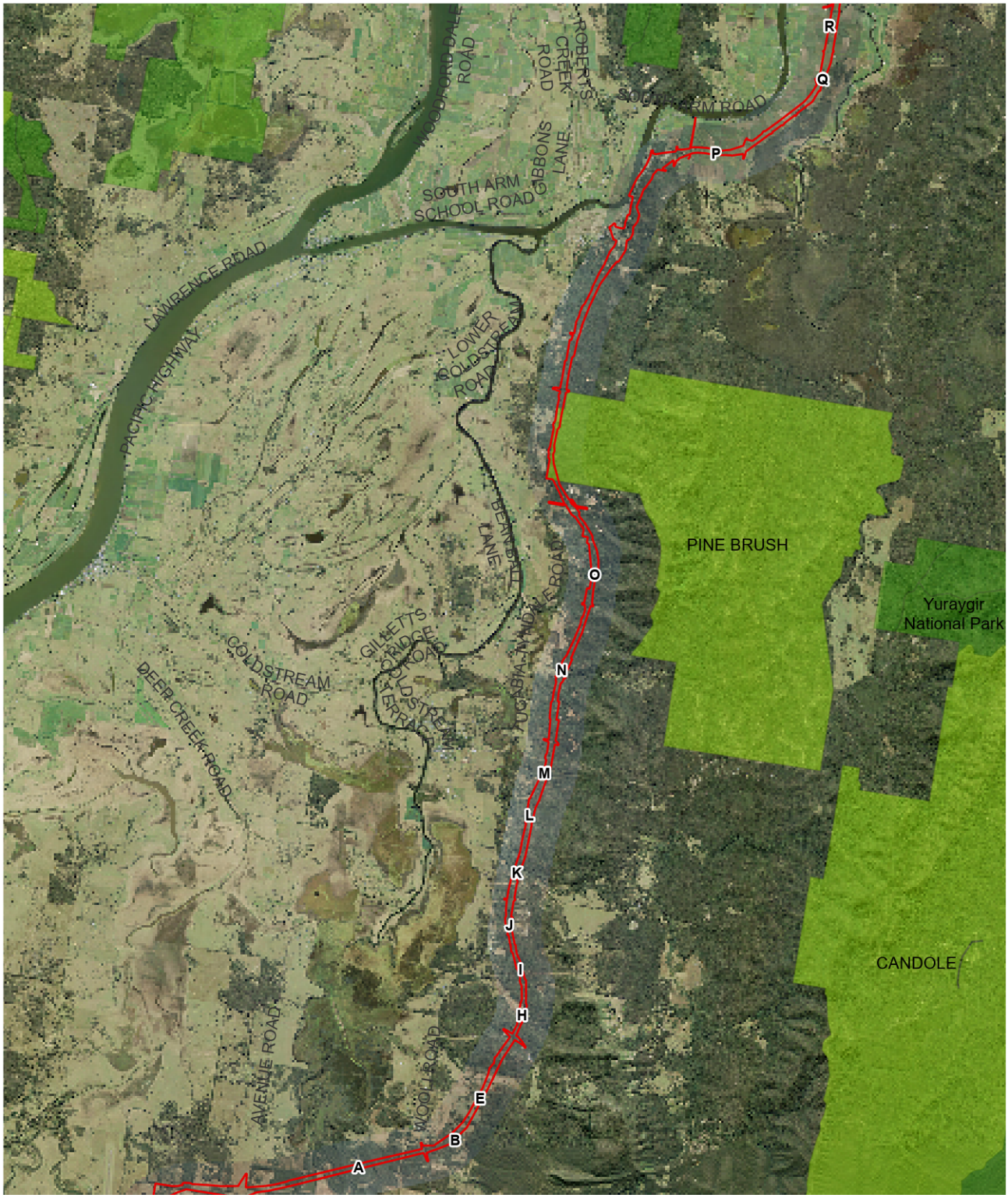
Details of the structures selected for the operational phase monitoring and the density of camera traps (*n=53*) are presented in Table 2-4 and shown in Figure 3.

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)



Legend

- Approved Project Boundary
- State Forest
- NPWS Reserve
- Emu bridge monitoring sites

1:130,000 @ A4

N

0 3 6 km

Data sources

Jacobs 2023, Pacific Complete 2017, LPI 2017, Imagery Service Layer

Figure 3 | Location of bridge monitoring sites

Monitoring of Emu usage at each potential crossing structure occurred continuously through the third year of operation (December 2022-December 2023 for 371 days ~ 53 weeks). This involved the placement of camera traps (Stealth Cam GN45 and Swift Enduro) 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 1 second in attempt to capture direction of travel and pairs or groups of Emus or confirm juveniles with adults. Cameras were operational for average of 91 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 malfunctioning cameras were replaced at the end of the quarter when required. Occasionally units were affected by moisture during excessive wet periods and flow below bridges and needed to be replaced.

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 2023 operational phase monitoring; op7 summer, op8 autumn, op9 winter, op10 spring; n.s = not set; c.m = camera malfunction, C.F = battery fatigue, FL = camera flooded, not replaced; STL = camera stolen after setting, not replaced

Site No.	Section	Cam	Camera days					Active weeks	Notes
			op11	*op12*	*op13*	*op14*	*total*		
A	3	A1	91	98	91	91	371	53.0	
		A2	55	49	92	91	287	41.0	
		A3	91	98	92	77	358	51.1	
		A4	n.s	98	92	91	281	40.1	A4 failure in op10, unit replaced op12
		A5	41	37	39	91	208	29.7	Duration affected by moisture
						mean	*301*	*43.0*	
B	3	B1	91	98	91	91	371	53.0	
		B2	91	98	91	91	371	53.0	
		B3	16	98	91	14	219	31.3	
		B4	c.m	98	c.m	14	112	16.0	cam malfunction op11&13, unit replaced
						mean	*268*	*38.3*	
C	3	C1	91	98	91	91	371	53.0	
		C2	91	98	0	91	280	40.0	
		C3	91	98	91	91	371	53.0	
		C4	n.s	98	51	91	240	34.3	cam c4 replaced in op12
						mean	*316*	*45.1*	
D	3	D1	91	98	91	91	371	53.0	
		D2	91	98	91	91	371	53.0	
						mean	*371*	*53.0*	
E	3	E1	91	98	91	91	371	53.0	
		E2	91	98	91	91	371	53.0	
						mean	*371*	*53.0*	
F	3	F1	91	98	91	91	371	53.0	
		F2	71	c.m	c.m	91	162	23.1	Cam failure, unit replaced
		F3	c.m	98	91	91	280	40.0	cam failure, unit replaced
		F4	91	98	91	91	371	53.0	
						mean	*296*	*42.3*	
G	3	G1	91	98	91	91	371	53.0	
		G2	91	98	91	91	371	53.0	
		G3	91	98	91	91	371	53.0	
		G4	91	98	91	91	371	53.0	
						mean	*371*	*53.0*	
H	3	H1	91	98	91	91	371	53.0	
		H2	91	98	91	89	369	52.7	H2 b.f in op 14
		H3	91	98	91	91	371	53.0	
		H4	91	98	91	91	371	53.0	
						mean	*371*	*52.9*	
I	3	I1	91	98	91	91	371	53.0	
		I2	91	98	91	91	371	53.0	

						mean	*371*	*53.0*	
J	3	J1	91	98	91	91	371	53	
						mean	*371*	*53.0*	
K	3	K1	91	98	91	91	371	53.0	
		K2	91	98	91	91	371	53.0	
		K3	91	98	91	91	371	53.0	
		K4	91	98	91	91	371	53.0	
						mean	*371*	*53.0*	
L	3	L1	91	98	91	91	371	53.0	
		L2	91	98	c.m	91	280	40.0	Cam malfunction in op13, unit replaced
						mean	*326*	*46.5*	
M	3	M1	91	98	91	91	371	53.0	
		M2	91	98	91	91	371	53.0	
		M3	91	98	91	91	371	53.0	
		M4	91	98	91	91	371	53.0	
						mean	*371*	*53.0*	
N	3	N1	91	98	c.m	91	280	40.0	cam malfunction in op13, unit replaced
		N2	91	98	37	91	317	45.3	
		N3	91	98	91	91	371	53.0	
		N4	91	98	91	91	371	53.0	
						mean	*335*	*47.8*	
O	3	O1	91	98	91	91	371	53.0	
		O2	91	98	91	91	371	53.0	
						mean	*371*	*53.0*	
P	4	P1	91	98	91	91	371	53.0	
		P2	91	98	91	91	371	53.0	
						mean	*371*	*53.0*	
Q	4	Q1	91	98	91	91	371	53.0	
		Q2	91	98	91	91	371	53.0	
						mean	*371*	*53.0*	
R	4	R1	43	n.s	53	91	187	26.7	
						mean	*187*	*26.7*	

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 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.

2.4.2 Crossing structure 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 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 property owners captured below each bridge.

2.4.3 Limitations

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, in some cases additional cameras have been added to the transect also to address the limitation.

The hybrid emu fence and gate constructed across chainage 51.2900 has been modified by the adjacent landowner through the addition of mesh wire to prevent sheep from leaving the property. This change has likely impacted the permeability of the fence to emus and limit access to the crossing structure monitored as site L. TfNSW has made contact with the landowner to explore opportunities to adjust fencing to restore the emu hybrid fence, however the landowner has advised that the netting is required for sheep exclusion. There is currently no opportunity to rectify this section of fence, however monitoring is continuing at this site.

3. Results

3.1 Emu presence

3.1.1 Sign searches

Signs of Emu presence was recorded from each of the impact and control survey areas in at least one season during the third 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 Tucabia south). The 2023 monitoring period reported emu sign and evidence of emu presence on the western side of the highway from one transect at Tucabia south (MRC) in the summer period (Feb 2023). This is the same location as reported in the 2022 annual report, which was recorded in the autumn-winter seasons of 2022, and considered the same bird. The 2022 report identified that this emu likely crossed the highway from the Mitchell Road underpass, as there was no reported crossing of a monitored bridge undercarriage north or south of this location during 2022 or 2023. There was no further evidence of emu activity identified on the western side of the highway after February 2023.

The density of Emu sign reported in the impact sites during the first 3 years of operation has increased at the Pillar Valley west and Tucabia north impact sites compared with the construction period, although the difference is not significant (*P=0.1160*). In contrast there has been a continued and significant decline in density at the Tucabia south study area across the three project phases. This decline is comparable with the data from the control sites in Yuraygir north (Fig 5) which have also declined significantly between construction and operation (*P=0.004*). The decline at both treatments is considered likely to be related to the movement of individual emus away from the monitoring transects which has occurred at both impact and control sites and would be consistent with low numbers of birds moving through the landscape. This is supported by the presence of emus at the remaining two impact study areas.

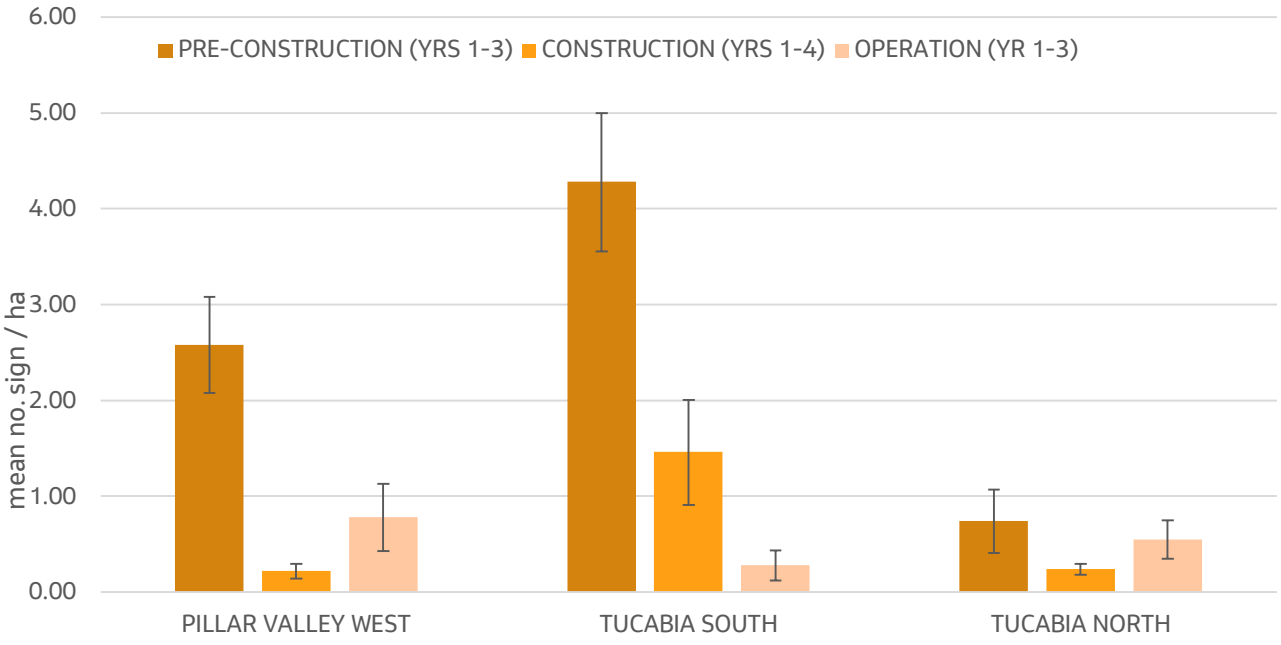


Figure 4: Mean density of Emu sign (no./ ha ±se) at impact survey areas comparing pre-construction (2014-16) and construction (2017-20), and operation (June 2020 to Dec 2023)

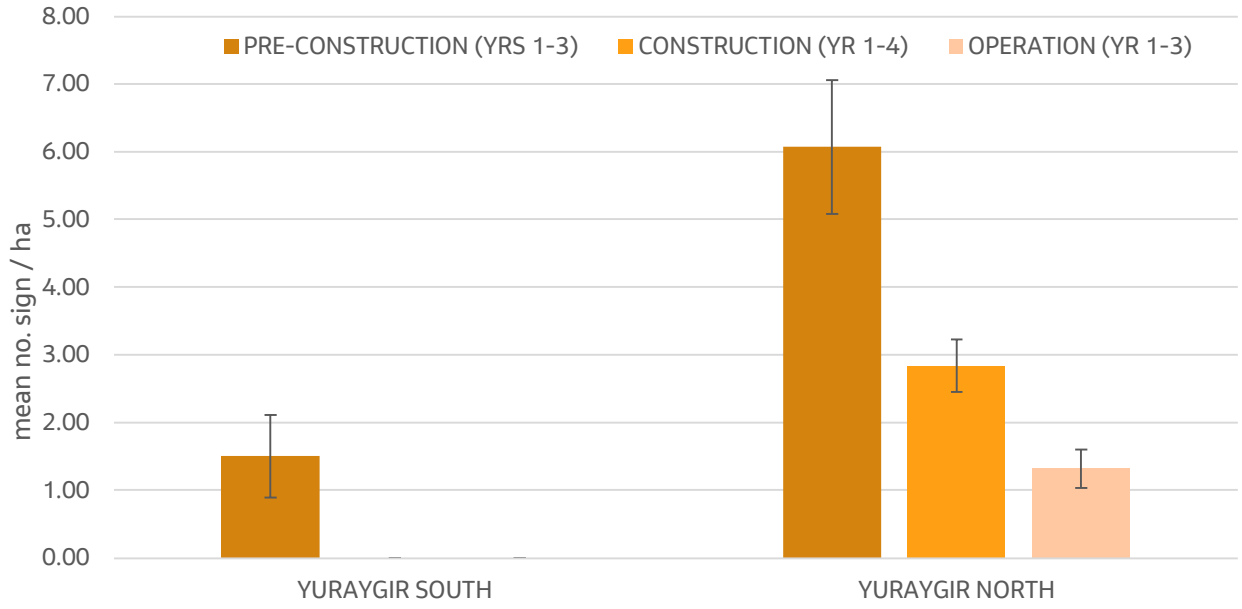


Figure 5: Mean density of Emu sign (no./ ha ±se) at control sites comparing pre-construction (2014-16) and construction (2017-20) and operation (June 2020 to Dec 2022)

It is difficult to compare the density of emu sign during construction and operation with the baseline (pre-construction) data as the coastal emu population was higher across the range of the population at the time. Thus, comparison of the change in density of emu sign between pre-construction, construction and operation has been interpreted with consideration of the temporal patterns of Emu sign observed across the impact and control 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 (refer 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 and is associated with population level decline. Of importance is comparison of density between the construction and operation phases considering the lower population data, which shows an increase (non-significant) in density post-construction from the two impact study areas at Pillar Valley west and Tucabia north. Similar increases have not been observed in the control study areas at this stage of the monitoring.

The density of Emu signs has declined significantly in the Yuraygir (north and south) control survey areas since collation of baseline data in 2014. 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 ($P = 0.004$). 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 mortality 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-Dec23 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*
	2020	-	-	0.00	0.00	-	*0.00*	*0.00*
	2021	0.00	0.16	-	1.12	-	*0.11*	*0.35*
	2022	1.28	4.00	2.72	0.48	-	*2.12*	*0.78*
	2023	0.16	0.16	0.00	0.00	-	*0.08*	*0.0*
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*
	2020	-	-	0.00	0.00	-	*0.00*	*0*
	2021	0.00	0.22	0.00	0.00	-	*0.05*	*0.05*
	2022	0.43	2.17	0.22	0.22	-	*0.76*	*0.47*
	2023	0.43	0.00	0.00	0.00	-	*0.11*	*0.11*
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*	*0.1*
	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*
	2020	-	-	0.00	2.46	-	*1.23*	*1.23*
	2021	1.70	0.38	0.00	0.38	-	*0.62*	*0.37*
	2022	0.38	0.57	0.00	0.19	-	*0.28*	*0.12*
	2023	0.76	0.38	0.00	0.00		*0.29*	*0.18*

*no survey conducted due to covid lockdown

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-Dec23 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*
	2022	0.00	0.00	0.00	0.00	-	*0.00*	*0.00*
	2023	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*
	2022	1.36	2.00	3.00	2.15	-	*2.13*	*0.34*
	2023	0.32	0.00	0.64	0.00	-	*0.24*	*0.15*

*no survey due to covid lockdown

3.1.2 Camera trapping

During the year three operational monitoring Emus have been photographed at 2 of the 20 transects surveyed (10 %). This is compared with 61.1 %, 40 % and 30 % recorded during the 3-year pre-construction monitoring period and 25 %, and 5 % in year 1 and 2 of operation. Mean camera trap rates in impact and control areas are shown in Figure 6, these show comparison of pre-construction data (2014-2016) with construction (2017-2020) and operation (June 2020-2023) and show a similar decline from the baseline in both impact and control areas. Camera trap success rates from the operational data at the impact sites has declined significantly from the baseline rate (P = 0.005). While camera trap success rates in control areas have increased during operation compared with lower construction sampling data but remains lower than the baseline. The decline between pre-construction and operation is a marked decline, but not statistically (*P = 0.07*) (**Figure 6**).

The decline in Emu camera trap success rates for three years of operation, compared to pre-construction trap rates in the impact areas remain high at around 82 %, although is an improvement from the first year of operation which was reporting 88 %. While the difference for control areas has reduced to only 39 % decline during operation, although this is notably greater than the first year of operation at 12 % and is the result of no emus being photographed at the control areas in 2023. 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 in the winter and spring of 2022 and abundant signs of emu presence were reported across all seasons of 2022 in the Pillar Valley west impact area. Then in 2023 no camera images were recorded in impact areas but were recorded in the Yuraygir north control area after an absence of images in 2022.

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

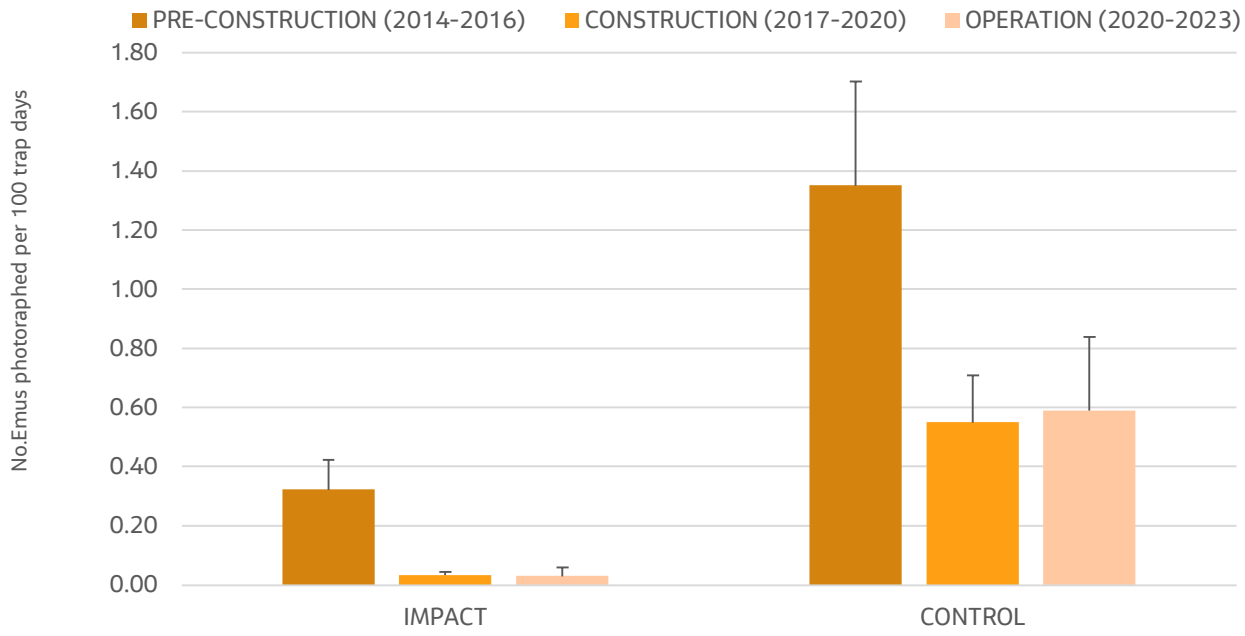


Figure 6: Mean camera trap rates (no. Emus photographed per 100 trap days ±se) at impact and control study areas for pre-construction period (2014-16), construction period (2017-20) and operation (Jun 2020-2023)

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 success 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 commenced.

A one-way ANOVA (test of variance) was performed on the annual camera trap success rates at each impact site comparing the pre-construction years (before) with the operational data (after). There have been declines in two impact areas, which are statistically significant, with a significant increase in trap rates at the Tucabia north impact area (*P=0.107*) compared with an absence reported in the baseline.

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 particularly operation compared with the baseline data, however this has also been noted from controls areas and the factors relating to this are unknown. There was a slight increase in presence of dogs in both impact and control areas during 2023 compared with 2022, however the patterns of impact and control areas remains similar.

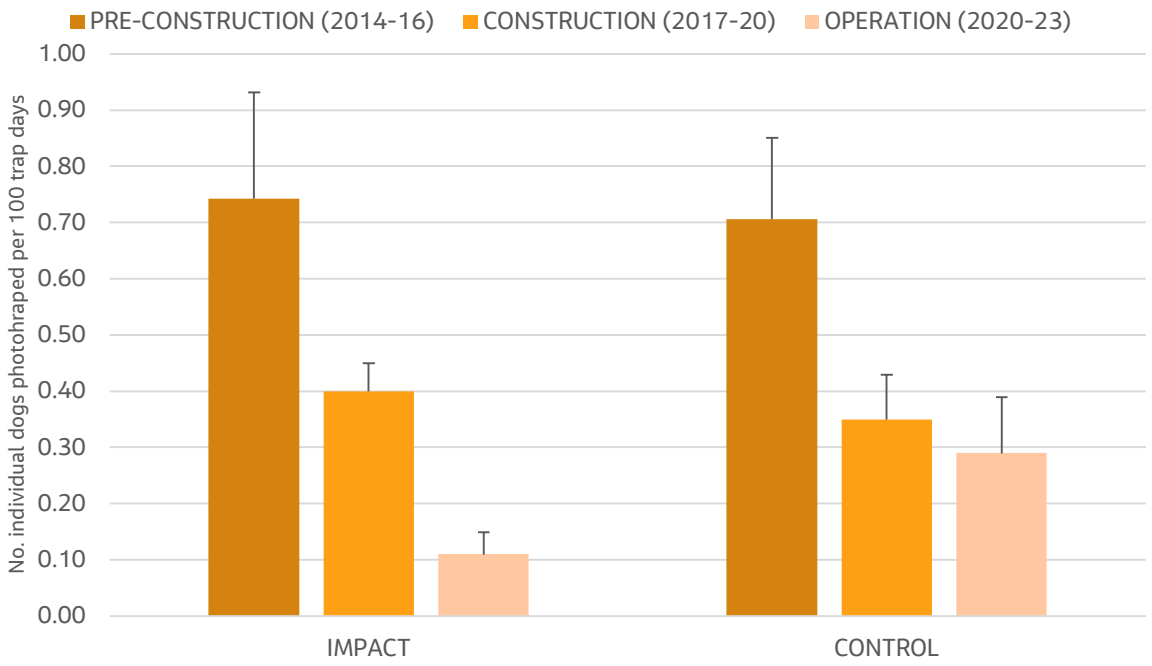


Figure 7: Mean camera trap rates (no. dogs photographed per 100 trap days ±se) at impact and control study areas for pre-construction (2014-16), construction (2017-June 20) and operation (June 2020- 2023)

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 years 1-2 operation (June 2020-2023)

Sampling period	Year	Summer	Autumn	Winter	Spring	Summer	*Mean*	*SE*
Pillar Valley west	*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*
	2022	0.00	0.00	0.00	0.00		*0.00*	*0.00*
	2023	0.00	0.00	0.00	0.00		*0.00*	*0.00*
Tucabia south	*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*
	2022	0.00	0.00	0.00	0.00		*0.00*	*0.00*

	2023	0.00	0.00	0.00	0.00		*0.00.*	*0.00*
Tucabia north	*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*
	2022	0.00	0.00	0.34	0.48		*0.21*	*0.12*
	2023	0.00	0.00	0.00	0.00		*0.00*	*0.00*

*No survey due to covid lockdown

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. There was a notable absence of emus from both impact and control areas in the spring period of 2023.

Data from the site occupation shows similar trends between the impact and control sites and reflects a general decline in emu presence across the region irrespective of the highway construction. These data have been collected over a period of ten years. **Figure 8** 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 14 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 55.6 % (*P=0.00*), while the proportion of control sites occupied by Emus has also declined significantly by 46.2 % (*P=0.002*). 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 %). The decline at the control sites has been most notable in 2022 (mean 10.7 refer table 3.4) and this is considered likely associated with a change which has occurred at the YNA transect, whereby the original fence line was replaced in 2021 with new fence that may be a barrier to emu movements. An additional camera has been added to this site, which has improved the detection rate slightly.

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 2020 green) and operation (June 2020-Dec 2023 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*
	2022	30.77	53.85	30.77	38.46	*38.46*	*5.44*
	2023	23.08	15.38	0.00	0.00	*9.62*	*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*
	2022	14.29	14.29	0.00	14.29	*10.71*	*3.57*
	2023	14.29	14.29	28.57	0.00	*14.29*	*5.83*

*No survey due to covid lockdown, occupation determined by camera data only

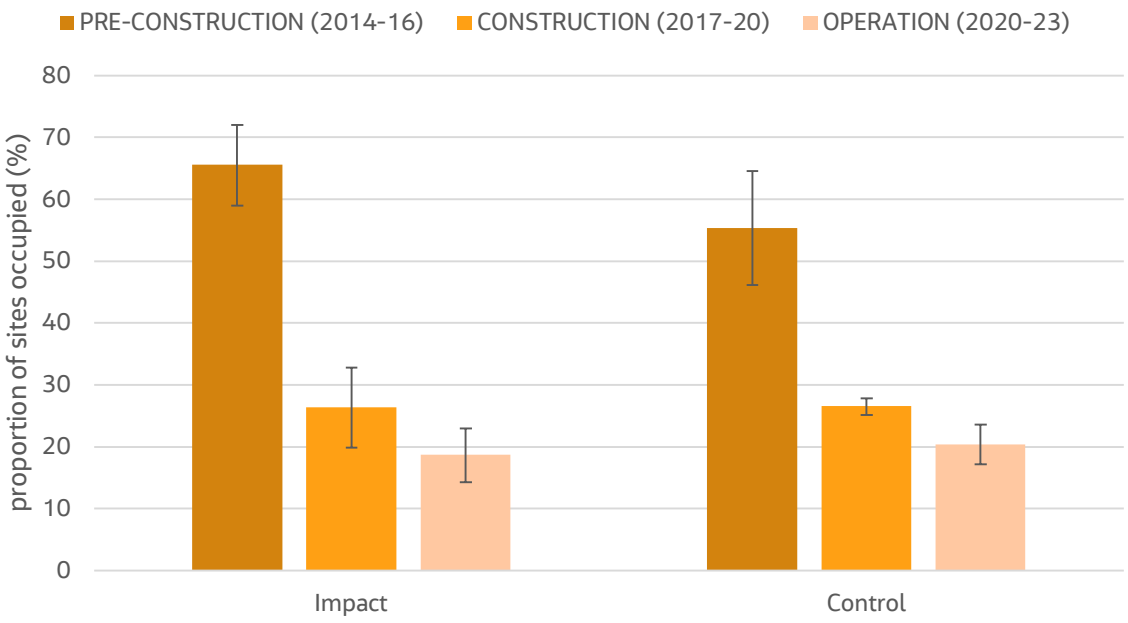


Figure 8: Mean site occupation rates (±se) for impact and control sites comparing pre-construction (2014-16), construction (2017-June 20) and operation (June 2022- Dec 2023)

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 2023 for the current report (42 months). In total 51 cameras were deployed across 18 structures (15 bridges in Section 3 and 3 bridges in Section 4). All monitoring sites were generally operating for between 38-53 weeks with brief camera malfunctions reporting in 9 units resulting in battery fatigue or SD card failure and a number of cameras were replaced. Important to note that several monitoring sites in section 3 recorded a significant amount of data triggered from cattle movements leading to brief battery fatigue. The use of multiple cameras reduced any limitation.

Emus were confirmed crossing the highway on 828 occasions from three separate bridges in section 4 of the project, relating to the large Shark Creek bridge, Site R (n=103) and the two small cane drain bridges south of shark creek, site P (n=633) and Site Q (n=92). No Emu crossings were captured in section 3 in the 2023 monitoring period. The frequency of Emu crossings in the sugar cane properties in Section 4 has increased from 35 crossings reported in 2021 to 209 crossings captured in 2022 and 828 crossings in 2023. This includes single adults, pairs and juvenile birds making regular crossings to access habitat east and west of highway with a peak recorded in spring.

There were no crossings captured in Section 3 despite the reported presence of birds from the sign survey and camera trapping in habitats to the east of the project in proximity to the highway. This absence of crossing corelates with the low occupation rates of birds in section 3 compared with Section 4. The absence of a confirmed crossing suggests there has been no presence of emu activity to the west of the highway in Section 3 in the 2023 monitoring period. Further structure monitoring is required to identify emu presence to the west of the highway in Section 3 and may be informed also with a review of monthly emu sightings recorded from public database, refer recommendations is chapter 5.

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 three years of operation

Section	Monitoring structure (*raised) (^landscape plantings)	Emu camera detections			Mean no. weeks cameras active (2022)	Mean emu crossing detections per active week
		2021	2022	2023		
Section 3	A *^	0	0	0	43.0	0.0
	B *^	0	0	0	38.3	0.0
	C *^	0	0	0	45.1	0.0
	D *^	0	0	0	53.0	0.0
	E *	6	0	0	53.0	0.0
	F *^	18	1	0	42.3	0.04
	G *^	0	0	0	53.0	0.0
	H *^	0	0	0	52.9	0.0
	I *^	0	0	0	53.0	0.0
	J *^	0	0	0	53.0	0.0
	K *^	0	0	0	53.0	0.0
	L ^	0	0	0	46.5	0.0
	M *^	0	0	0	53.0	0.0
	N *^	0	0	0	47.8	0.0
	O ^	0	0	0	53.0	0.0
	total	*24*	*1*	*0*	*739.90*	*0.0 (mean section 3)*
						0.0 (se)
Section 4	P ^	4	174	633	39.5	11.94
	Q ^	0	3	92	32.6	1.74
	R*	31	32	103	13.0	3.86
	total	*35*	*209*	*828*	*85.1*	*5.85 (mean section 4)*
						3.11 (se)

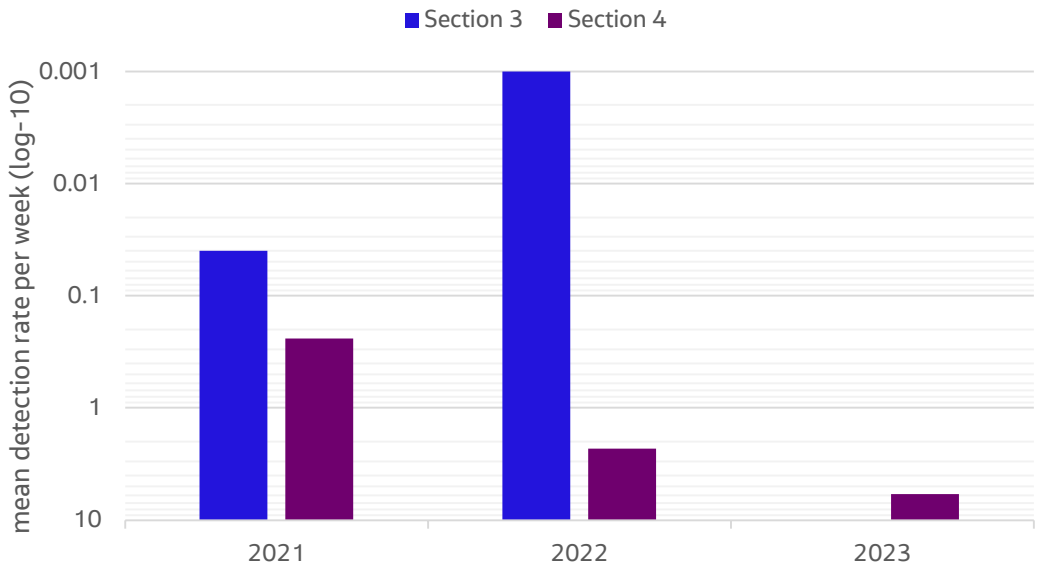


Figure 9: Mean detection rates / per week (log-^{10}) for emus photographed using bridges to cross highway in year 1- 3 operation in section 3 and 4

Plate 7. Shark Creek bridge (Site R) adult male and striped chicks in late spring period

Plate 8. Shark Creek bridge (Site R) bird regularly crossing in all seasons

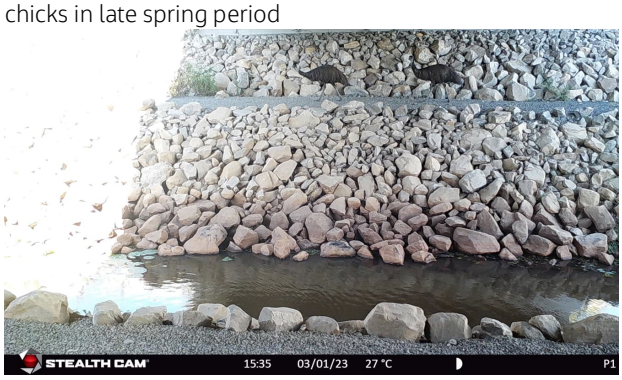


Plate 9. Cane drain (site P) Pair crossing to the west

Plate 10. Cane drain (Site P) Pair crossing to the east

Plate 11. Cane drain (P) crossing to the east during spring season

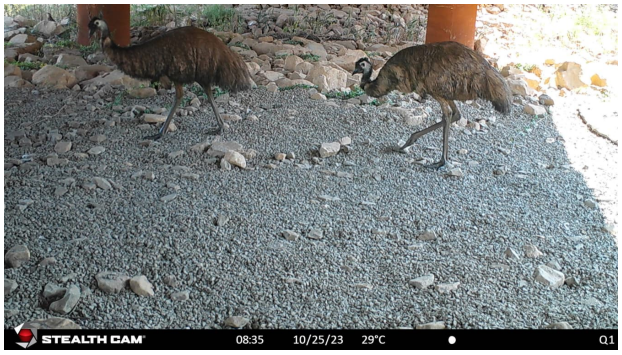


Plate 12. Cane drain (P) crossing to the west during spring

3.2.2 Fence and roadkill monitoring

There were no reported emu road strike incidents on the Pacific Highway corridor in the 2023 monitoring period and no signs of trapped or dead emus along the exclusion fencing in proximity to any of the monitored crossing structures.

3.2.3 Dog detections

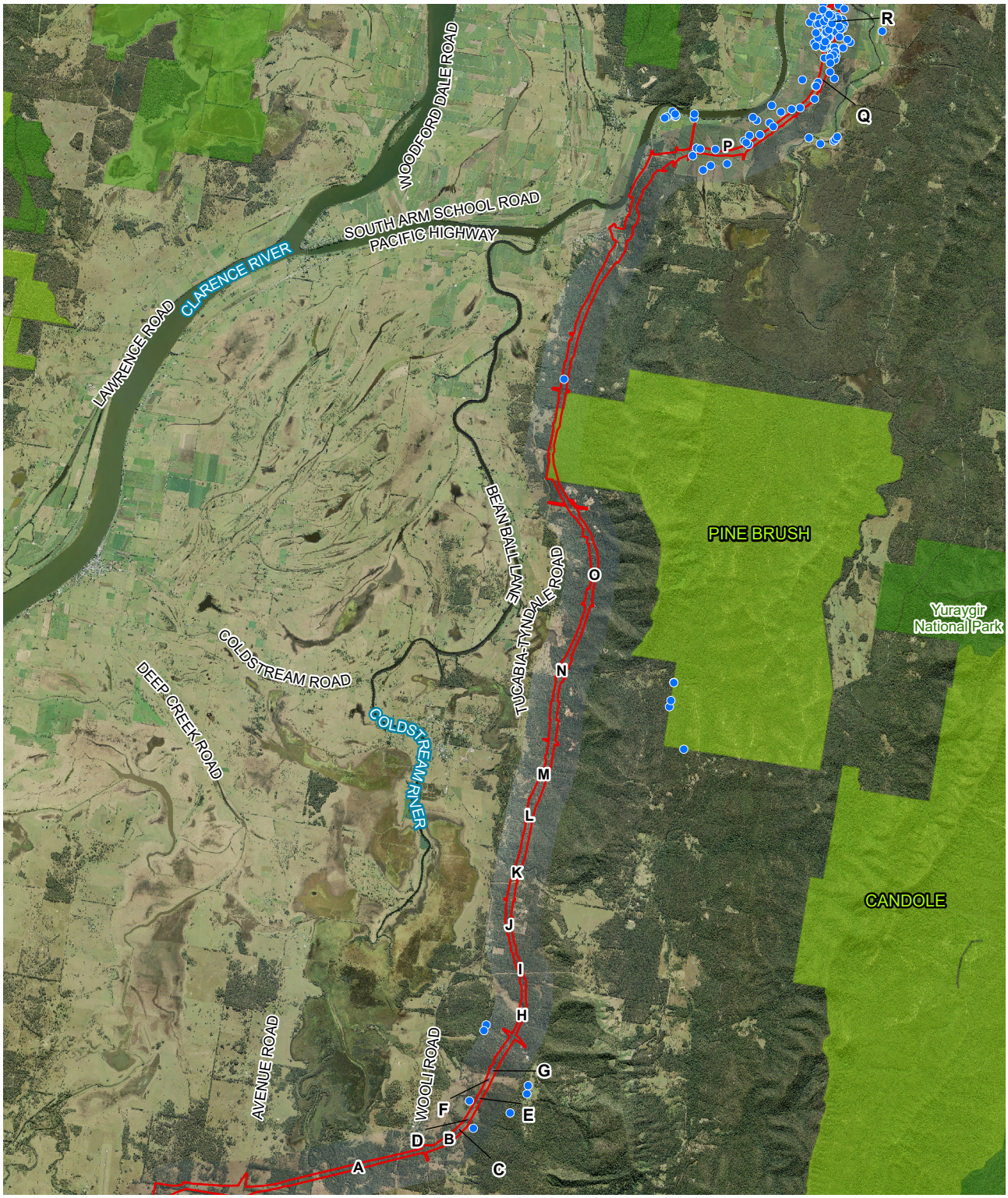
In the first three years of operation dogs have been recorded using the bridge underpasses to cross the highway in grazing, cropping and forested areas of the project in both section 3 and section 4. There were 0.09 detections per week in section 3 in 2023 compared with 0.11 detections per week in 2022 and 0.01 in 2021. In section 3 the highest number of detections were recorded at site A, south of Pillar Valley Creek averaging 1.07 detections per week, this property owner is aware and has been actively controlling dogs.

Dogs were recorded crossing the highway in section 4 for the first time since monitoring commenced with 0.44 detections per week across both cane drains (site P and Q). The presence of dogs using the cane drain bridges does not seem to have impacted emu crossings which have increased in the last 12 months of monitoring. Given this observation, it is reasonable to suggest that the presence of dogs using structures to cross the highway on

Section 3 is not negatively influencing the use by emus and dog activity has not significantly increased in the last 12 months.

3.2.4 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 Appendix A, 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. All sightings in section 3 are reported east of the highway.



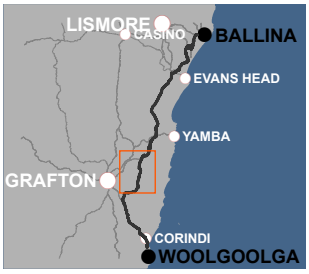
Legend

- Approved Project Boundary
- Dromaius novaehollandiae (BioNet records)
- State Forest
- NPWS Reserve

1:130,000 @ A4

N

0 3 6 km



Data sources

Jacobs 2024, Pacific Complete 2017, Department of Customer Service 2024

Figure 10 | Emu sightings and sign recorded during the 2023 operational monitoring phase

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 third year of highway operation are discussed below.

4.1 Emu activity and site occupation

Emu activity and site occupation during the third year of 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. When comparing occupancy 'before' construction with 'after' construction, the proportion of impact sites occupied by Emus has declined significantly by 55.6 %, while the proportion of control sites occupied by Emus has also declined significantly by 46.2 %.

Emu presence was recorded from each of the impact and control survey areas in at least one season during the 2023 monitoring period, with the exception of the Yuraygir south survey area (control). The density of sign in two of the three impact study areas has increased in the operational period compared with the construction period associated with emus returning to the project area post-construction. In contrast there has been a continued and significant decline in the density of sign at the Tucabia south study area. This is comparable with declines noted at control study areas and therefore is unlikely to be project related. The 2023 monitoring period reported emu evidence of at least one emu that was temporarily present on the western side of the highway in the Tucabia south study area in the summer season.

Despite the overall occupancy of emus remaining significantly lower than the baseline (pre-construction) in impact areas, the presence of emus reported in impact sites during the 2023 operational period may reflect current availability of food resources in these locations following repeated high rainfall events in 2021 and 2022 after periods of drought during late construction. Emus are known to be nomadic, keeping in touch with variation in availability of food which is influenced by rainfall (Davies 1976; 1984) and is widespread across large areas. Since the start of the operation phase, from late 2020 to autumn 2022, above average rainfall in the W2B project area has been associated with the presence, albeit low-density, of emus reported in two of the three impact study areas during the operational phase of the monitoring to date. The lower density of emu sign and trap rates likely reflects decline in the population overall rather than project related as is consistent with the long-term data from impact and control sites.

As noted, the decline in emu presence compared with before and after construction has been reported in the impact monitoring sites in section 3 of the project. In the cane properties surrounding section 4 of the project, Emu presence has been continually reported in all seasons near the highway during both periods and has continued during the 2023 operational monitoring. This has been determined comparing direct observations made from the highway between the Tyndale interchange to Shark Creek bridge in addition to photographs captured below crossing structures (P-R). Indeed, pairs and small groups of birds, chicks and sub-adults were all recorded in 2023 indicating breeding success in these modified agricultural habitats adjoining the highway, and the importance of this habitat in providing food resources and watering points for breeding birds and juveniles.

4.1.1 Performance thresholds and corrective actions

The monitoring of emu presence has been designed to provide a baseline of emu occupation 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 14 operation phase surveys. When comparing occupation 'before' construction with occupation 'after' construction, the proportion of impact sites occupied by Emus has declined significantly by 55.6 % over a 9-year period (2014-2023), although this is an improvement from year one operation was which 72.9 %. In this same period the proportion of control sites occupied by Emus has also declined significantly by 46.2 % compared with 28.3 % at the end of year one operation. Both declines are >15 % from the baseline, although importantly, at 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 %). While there is a greater reported decline at the impact sites, there is only a difference of 9.4 % between the treatments (i.e., <15 %). The decline at the control transect YN-A in the last 12 months is thought to be influenced by physical changes at the site with the replacement of the boundary fence and clearing which has been done by the landowner. As per the recommendation in the last report an additional camera trap was added to the transect in November 2023 to potentially increase detection rates.

The direct observations made during year three operation have recorded evidence of breeding activity in Section 4. Groups of adult birds have been observed in the autumn-winter breeding period and the presence of juveniles with male parent (see Plate 7). The data over the last three years of operational monitoring suggests that the project has not impacted emu breeding success.

4.2 Monitoring effectiveness of crossing structures

The first three years of 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 three locations, all in Section 4. The use of the three bridges in section 4 has increased each year over the three-year operational period and demonstrates regular east and west crossings in the last 12 months across a 4 km section of highway. The frequency of use is consistent with the high number of direct observations and higher emu density reported in this part of the project. In comparison, emus have not been captured using any of the crossing structures in section 3 in the last 12-month period, which is monitoring over a 15 km section of highway. The absence of crossings in the 12-month monitoring period in section 3 is consistent with the low density of emu activity and low occupation rate, and emu activity has not been reported on the west side of the high since February 2023.

High usage rates of dogs at crossing structures in section 3 was reported in the 2022 monitoring report, with suggestion this may be negatively influencing emu usage. The rate of dog usage declined slightly in section 3 in 2023 and no emu crossings were captured. Dogs were however also recorded using the crossing structures in section 4, for the first time since operational monitoring commenced, with the mean number of weekly detections 20 % higher (n=3 structures) than all of section 3 (n=15 structures), in the same monitoring period. High dog activity at the crossing structures in section 4 has coincided with a peak in emu crossings over the same time, with these data suggesting that the presence of dogs using the bridges to cross the highway has not negatively influenced emu usage.

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 three operational monitoring confirmed usage of the crossing structures by emus, and birds have been detected by camera traps travelling in an easterly and westerly direction below bridges at three locations in Section 4. There has been no evidence of using crossing structures in section 3 in the reporting period, although emu sign was detected in the summer monitoring in 2023, on the west side of the highway at one location. No further evidence was reported after February. Monitoring of the three structures on section 4 in the third year of operation shows emus regularly crossing to the east and west of the highway to access habitat in agricultural areas. 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 and the bridge structures provide access to this habitat, despite the presence of dogs also regularly using the structures.

Emu usage of bridges in section 3 is showing comparatively limited usage, with no confirmed crossings in the current 12-month monitoring period, which is reflected in the low site occupation rates in section 3 and is a result of the lack of emu presence rather than avoidance of structures.

Dog activity at crossing structures has remained similar in section 3 to the previous 12-month operational monitoring and has increased in section 4. There were no recorded dog attacks at any if the crossing structures in this monitoring period and no dead emus found.

4.3 Exclusion fence monitoring

There were no Emu road-strike incidents reported during the third year of operation monitoring, and no evidence of injured or dead emus along the exclusion fence in proximity to the bridge structures or reported breach of the exclusion fence during the monitoring period.

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 two operation or breaching the exclusion fencing and entering the road corridor.

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

5. Recommendations

This report is the third year of operational monitoring for Coastal Emu associated with the W2B project, and monitoring has indicated that many of the performance thresholds for the effectiveness of mitigation measures are being met. This is because the patterns in site occupation rates have remained comparable between the impact and control sites during all three stages of the monitoring The exception is that emus have not been recorded using any crossing structures in section 3 in the current monitoring period despite the length of project being monitored, the number of sites and density of survey effort, (>50 camera traps over 12 months continuance monitoring of bridge structures). This result is consistent with the low occupation rates recorded in section 3 and the absence of emu activity recorded on the west side of the highway in section 3 since February 2023. The previous activity reported in 2022 on the west side was in proximity to the Mitchell Road overpass. Emus have been reported crossing in an easterly and westerly direction via three structures on section 4, indicating that the highway is not presenting a barrier to movement and the effectiveness of these structures for emu passage are evident.

Further ongoing monitoring is required to determine usage of crossing structures in section 3 and confirm presence west of the highway. There are limited opportunities for the addition of inclusion of new survey transects or increased monitoring equipment at the crossing structures, noting that the number of active monitoring weeks at the structures was already higher in 2023, then the previous two years. This is because there was no loss of equipment from flooding in 2023 as there was in the previous monitoring period.

The decline in emu density noted at the control site along the boundary of Yuraygir National Park at Taloumbi (TNA) is considered likely a function of the change in the environmental variables at this site. The change is associated with the addition of a newly constructed fence on private property and minor clearing which occurred at the end of 2021 and no emus sign has been detected since the activity. This suggests that the decline here is likely the result of bias in the survey data effecting the analysis rather than the absence of emus. An additional camera was placed on the transect in November 2023 and it is suggested this camera be retained until monitoring is complete.

Sightings of emus near the W2B project were recorded during the construction phase by contractors and TfNSW staff. There have been few observations during the operation phase, and additional sightings data may be obtained by liaison with Clarence Valley Council to obtain access to public sightings, this is important given the decline in the population and may assist to identify emus west of the project in Section 3.

Table 5.1: Recommendation following Year 3 operational monitoring and Transport for NSW response.

No.	Recommendation	Transport for NSW
1	Continue monitoring emu usage of crossing structures in section 3 and transects west of the highway to determine evidence of east-west movements within the 5-year performance period	Adopted
2	Continue to monitor the additional camera trap at the control site TNA as a means of detecting emu presence and confirm that the decline in activity is not due to survey bias	Adopted
3	Liaise with Clarence Valley Council to obtain monthly emu records collated on councils' emu sighting register and also access the BioNet database annually. This data would supplement observations in the project impact areas and assist to identify or confirm emu activity west of the highway in section 3 to supplement the transect and crossing structure monitoring.	Adopted

6. References

Clarence Valley Council 2020. Natural Resource Management Coastal Emus: Sighting Data Analysis July 2020

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

Jacobs (2014), Pacific Highway Upgrade Woolgoolga to Ballina Coastal Emu Monitoring Study: Phase 1: pre-construction Survey Report (pre-fencing)

Jacobs (2015), Pacific Highway Upgrade Woolgoolga to Ballina Coastal Emu Monitoring Study: Annual Report 2015 (Pre-construction)

Jacobs (2016), Pacific Highway Upgrade Woolgoolga to Ballina Coastal Emu Monitoring Program: Annual Report 2016 (Pre-construction – Baseline)

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

Jacobs (2018). Pacific Highway Upgrade Woolgoolga to Ballina Coastal Emu Monitoring Program: Annual Report 2018 (Construction Year 2)

Jacobs (2019). Pacific Highway Upgrade Woolgoolga to Ballina Coastal Emu Monitoring Program: Annual Report 2019 (Construction Year 3)

Jacobs (2020). Pacific Highway Upgrade Woolgoolga to Ballina Coastal Emu Monitoring Program: Annual Report 2020 (Construction Year 4)

Jacobs (2021). Pacific Highway Upgrade Woolgoolga to Ballina Coastal Emu Monitoring Program: Annual Report 2020 (Construction Year 5, Operation Year 1/2)

Jacobs (2022). Pacific Highway Upgrade Woolgoolga to Ballina Coastal Emu Monitoring Program: Annual Report 2020 (Construction Year 6, Operation Year 2/3)

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

Appendix A. Emu sign and sightings near the project during year 2 of operation

Table A.1 Opportunistic Emu observations made during operation of the highway in 2023, AD = Adult, SA = sub-adult, CH – striped chicks, Sect = project section

Date	AD	SA	CH	Sect	Easting	Northing	Location
15/02/2023	2			4	519025	6734263	shark creek flats in cane
22/02/2023	1			3	511462	6711975	Feather on barbed fence
22/02/2023	1			3	511411	6711849	Feather on barbed fence
22/02/2023	1			3	515501	6718991	Feather on barbed fence
22/02/2023	1			3	515534	6719129	Scat
22/02/2023	1			3	515596	6719531	Feather on barbed fence
22/02/2023	1			3	515599	6719522	Feather on barbed fence
23/02/2023	1			3	525476	6730969	Feather on barbed fence
17/05/2023	6			4	518731	6733564	shark creek flats in cane
30/05/2023	1			3	511179	6709694	Feather on barbed fence
31/05/2023	1			3	517044	5717625	Feather on barbed fence
31/05/2023	1			3	515818	6718055	Feather on barbed fence
2/06/2023	1			3	525421	6730442	Feather on barbed fence
23/06/2023	2			4	519251	6733765	shark creek flats in cane
23/06/2023	1			3	511989	6710032	Feather on barbed fence
23/06/2023	1			3	512360	6710452	Feather on barbed fence
23/06/2023	1			3	512387	6710635	Feather on barbed fence
14/10/2023	2			4	518847	6733656	shark creek flats in cane
14/10/2023	3			4	517611	6731921	shark creek flats in cane
14/10/2023	1			-	530955	6732440	Juv scat Bees Nest trail
14/10/2023	1			-	529780	6732765	Taloumbi feather on barbed fence
14/10/2023	1			-	529994	6721317	Feather on barbed fence
14/10/2023	1			-	529996	6721309	Sandon
1/03/2024	1	3		4	519922	6733813	on soya crop
1/12/2023	1			3	515843	6730740	Feather on barbed fence
2/12/2023	1			3	525485	6732314	Feather on barbed fence
2/12/2023	1			3	525593	6732298	Feather on barbed fence
2/12/2023	1			3	525633	6732294	Feather on barbed fence
2/12/2023	1			3	525669	6732284	Feather on barbed fence
2/12/2023	1			3	525691	6732279	Feather on barbed fence
2/12/2023	1			3	525891	6732249	Feather on barbed fence
2/12/2023	1			3	525900	6732245	Feather on barbed fence
2/12/2023	1			3	526089	6732215	Feather on barbed fence
2/12/2023	1			3	526141	6732201	Feather on barbed fence
1/12/2023	1			1	516204	6730686	Feather on barbed fence
2/12/2023	1			1	526263	6732184	Feather on barbed fence
2/12/2023	1			1	526281	6732180	Feather on barbed fence
2/12/2023	1			1	526436	6732154	Feather on barbed fence
2/12/2023	1			1	526468	6732151	Feather on barbed fence
2/12/2023	1			1	526481	6732150	Feather on barbed fence
2/12/2023	1			1	526587	6732197	Feather on barbed fence

3/12/2023	1			3	519111	6719397	Feather on barbed fence
3/12/2023	1			3	519106	6719420	Feather on barbed fence
3/12/2023	1			3	519106	6719431	Feather on barbed fence
3/12/2023	1			1	519106	6719432	Feather on barbed fence
1/12/2023	1			-	515878	6730384	Feather on barbed fence
3/12/2023	1			-	519095	6719507	Feather on barbed fence
3/12/2023	1			-	519006	6720214	Feather on barbed fence
3/12/2023	1			-	518987	6720367	Feather on barbed fence
3/12/2023	1			-	518980	6720403	Feather on barbed fence
3/12/2023	1			3	519107	6719318	Feather on barbed fence
3/12/2023	1			3	519048	6718994	Feather on barbed fence
3/12/2023	1			3	519141	6718954	Feather on barbed fence
3/12/2023	1			3	519397	6719214	Feather on barbed fence
3/12/2023	1			3	519394	6719398	Feather on barbed fence
3/12/2023	1			3	519393	6719424	Feather on barbed fence
1/12/2023	1			-	515874	6730378	Feather on barbed fence
3/12/2023	1			3	519367	6719449	Feather on barbed fence
3/12/2023	1			3	519365	6719448	Feather on barbed fence
3/12/2023	1			3	519284	6719421	Feather on barbed fence
3/12/2023	1			3	519215	6719401	Feather on barbed fence
2/12/2023	1			-	525372	6732333	Feather on barbed fence
2/12/2023	1			-	525411	6732325	Feather on barbed fence
2/12/2023	1			-	525417	6732324	Feather on barbed fence
2/12/2023	1			-	525475	6732316	Feather on barbed fence
2/12/2023	1			-	525477	6732331	Feather on barbed fence